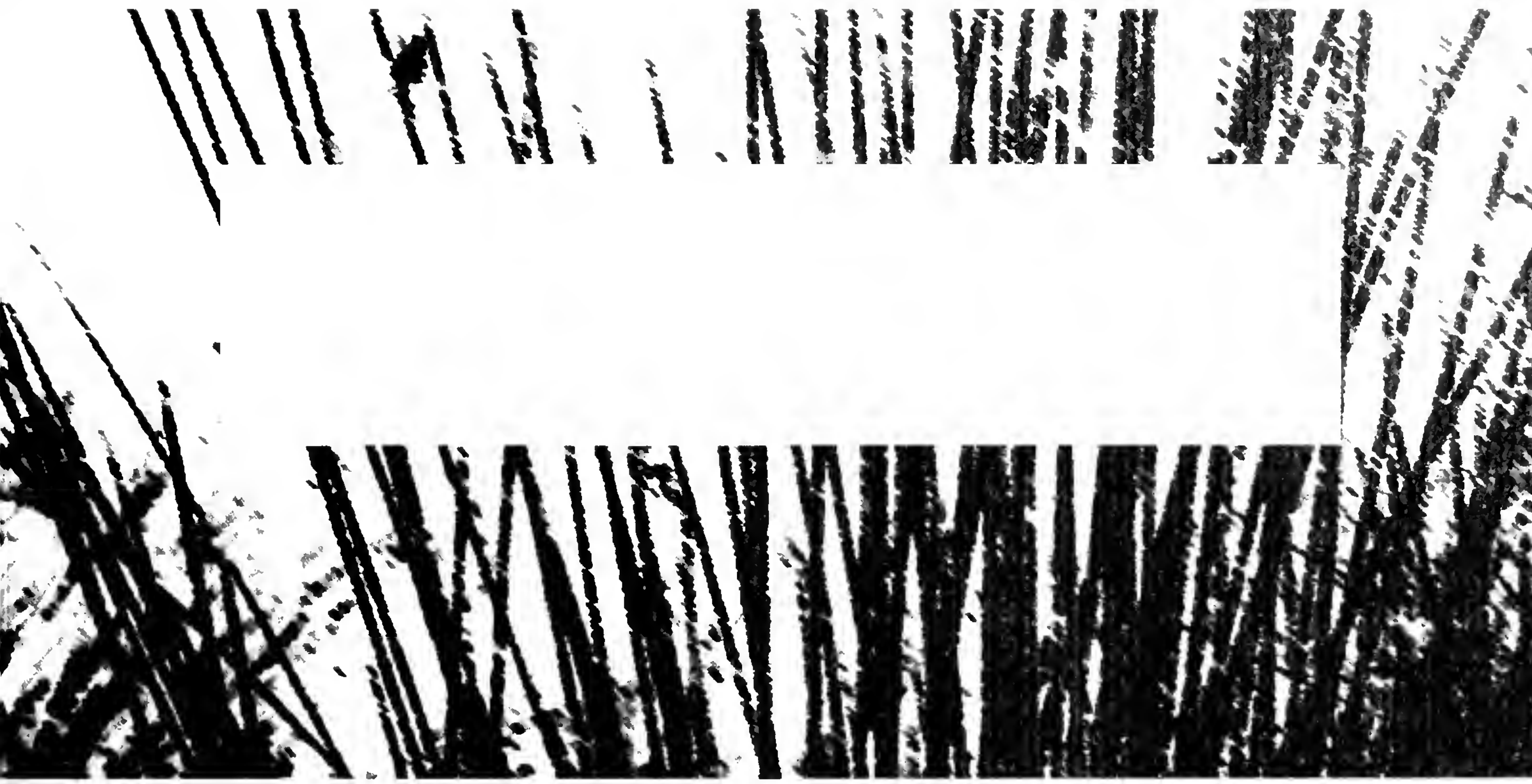
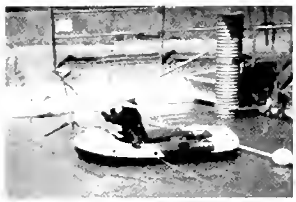


Prepared by the San Francisco Estuary Institute
for the Grassland Bypass Project Oversight Committee

Grassland Bypass Project



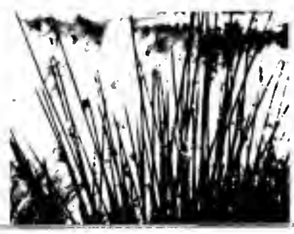
Prepared by SFEI for the Grassland Bypass Project Oversight Committee

U.S. Bureau of Reclamation
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Geological Survey
Central Valley Regional Water Quality Control Board
California Department of Fish and Game
San Luis & Delta-Mendota Water Authority

Grassland Bypass Project

Summary

Bob Young, Technical Team Leader
U.S. Bureau of Reclamation



Introduction

The Grassland Bypass Project (GBP) completed its fourth year of operations on September 30, 2000. This annual report documents results from the monitoring efforts for the fourth year, water-year (WY) 2000. Information from the first, second, and third year is included where appropriate. One function of the annual report is to document results from the multi-agency data collection effort. The report builds upon previous information, allowing for the discernment of changes in environmental conditions over time.

During the year, the Data Collection and Reporting Team (DCRT) continued to meet and review the monthly data and associated reports. DCRT meetings were held quarterly during the fourth year instead of monthly as in the previously three years. DCRT reviewed reports at their respective offices during the months meetings were not held. Also, under the auspices of the DCRT, four quarterly data reports, four quarterly narrative and graphical summary reports, and the third annual report were developed and approved for publishing. There were no public Oversight Committee (OC) meetings held during the year relating directly to the existing Project. Three public scoping meetings were conducted to begin the process of developing the Grassland Bypass Project EIS/EIR covering the period 2002 through 2009.

This annual report consists of technical chapters prepared by the agency staff responsible for each portion of the GBP monitoring program.

Project Authorization

The U.S. Bureau of Reclamation (USBR) signed a Finding of No Significant Impact (FONSI) on November 3, 1995 for use of a 28-mile segment of the San Luis Drain (SLD) (USBR, 1995). This segment conveys agricultural drainage waters from the Grassland Drainage Area (GDA) to the San Joaquin River via a 6-mile segment of Mud Slough (North). A map of the GBP area and a schematic diagram are presented in Figures 1 and 2. Analysis from an environmental assessment (EA) dated April 1991, and supplemented in November 1995, resulted in the FONSI.

A Use Agreement (UA) was also signed on November 3, 1995 between USBR and the San Luis & Delta-Mendota Water Authority (SLDMWA) (USBR and SLDMWA, 1995). The UA gives the terms and conditions of use of the SLD. The UA allows for renewal of the interim two-year use for no more than three years if certain conditions were met. On January 25, 1999, the OC recommended that the UA be extended until September 30, 2001.

The EA documents commitments made by participating agencies to address environmental benefits and risks. These commitments include the following:

- To ensure that progress continues toward long-term resolution of agricultural subsurface drainage management activities,
- To ensure that there are no significant adverse effects to fish and wildlife, other environmental resources, and public health, and
- To ensure that the above listed commitments are implemented and addressed as part of the Project.

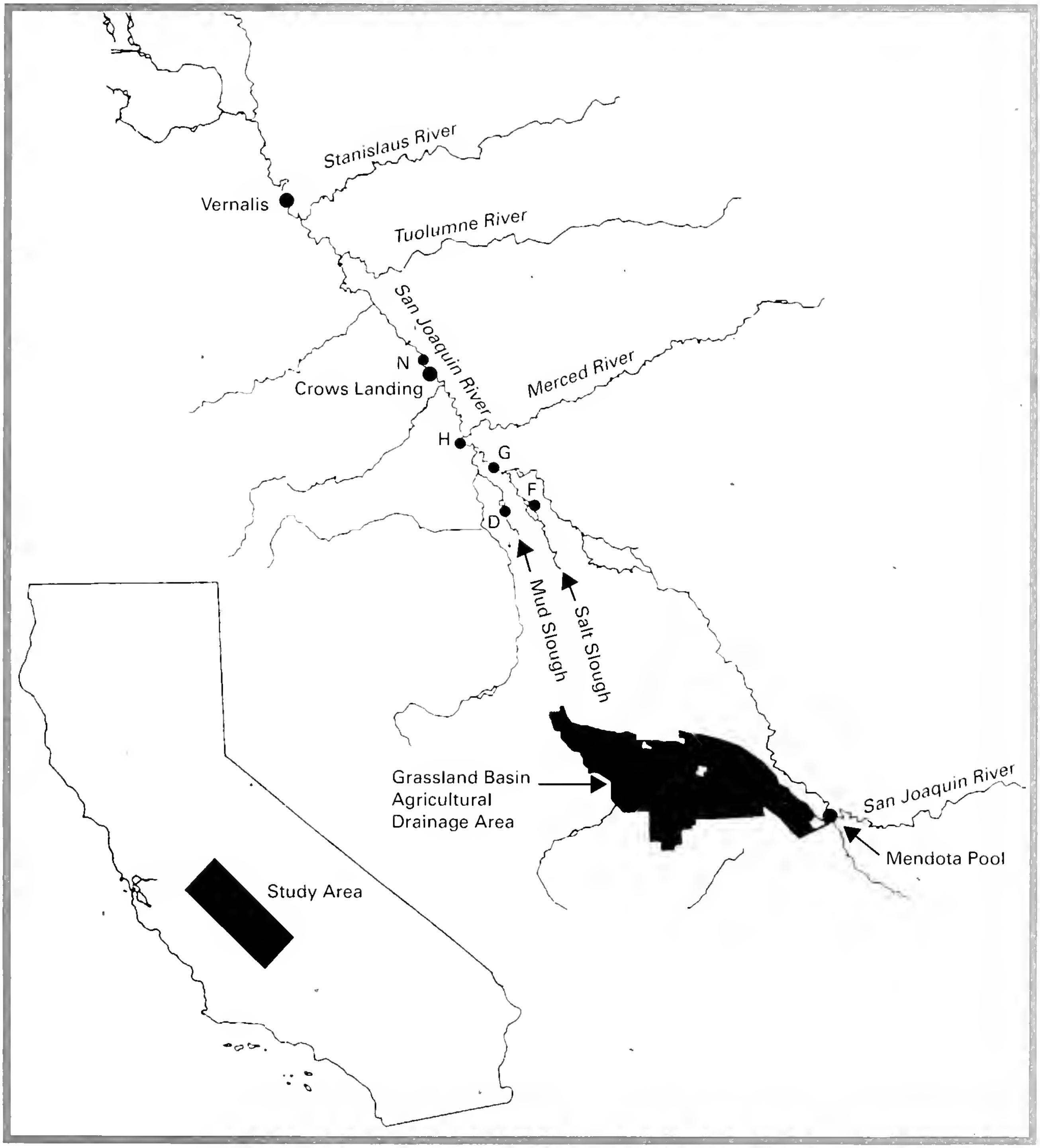
The EA also documented benefits and risks. The benefits include the following:

- Agricultural subsurface drainage water will be removed from the Grassland Water District (GWD) delivery channels, allowing refuge managers to receive and apply all of their fresh water allocations according to optimum habitat management schedules.
- Removal of agricultural subsurface drainage water from the GWD channels will reduce the selenium exposures to fish, wildlife, and humans in the wetland channels and Salt Slough.
- Combining agricultural subsurface drainage flows within a single concrete-lined structure allows for effective concentrated monitoring, leading to detailed evaluation and effective understanding of drainage flows and associated selenium loads.
- The establishment of an accountable drainage entity will provide the framework necessary for responsible watershed management in the Grassland Basin.

The documented risks included the following:

- Combining agricultural drainage flows within the SLD will result in an increase in selenium and other constituents which are discharged into Mud Slough (North). These constituents will be above the levels historically discharged to Mud Slough (North) and could have an adverse environmental effect on six miles of Mud Slough (North).
- Agricultural drainage flows entering wetland channels during floods.

Figure 1. Map of the Grassland Bypass Project



1999–2000 Highlights

During water year 2000, monthly selenium loads discharged from the terminus of the SLD were all below the load values agreed upon in the UA (Figure 3a, Tables 1 and 2). The annual discharge amount, 4,603 pounds, was 23 per cent below the annual load value, 5,994 pounds. For comparison purposes, monthly discharges are also provided for water years 1997, 1998, and 1999 (Figures 3b, c, and d).

Concurrent Activities

Additional management and/or technical activities were either initiated or continued during the year. These activities include the following:

1. Second Agreement for use of the San Luis Drain

   Reclamation and the San Luis & Delta-Mendota Water Authority are negotiating a new agreement to continue the Grassland Bypass Project through December 31, 2009. An Environmental Impact Statement/Environmental Impact Report has been prepared to evaluate the consequences of this agreement. A revised Waste Discharge Requirement will be issued by the CVRWQCB for the new Project that will reduce the monthly and annual loads that may be discharged from the Project into Mud Slough and the San Joaquin River.

   The EIS/EIR studied three alternatives: 1) continue the current Project with minor changes 2) No Action Alternative (i.e., no agreement to use the San Luis Drain), and 3) Mud Slough Bypass Alternative.

2. "Sources of Selenium" studies

   Heavy rainfall during the first two Project years resulted in selenium load discharges exceeding load values. On-farm management activities were not able to control the excessive rainfall and associated storm runoffs through project boundaries. As a consequence, discharges through the San Luis Drain, and in some cases wetland channels, were above what was planned. The Oversight Committee recommended that additional studies be undertaken to establish the sources of selenium. Numerous studies are currently being performed.

3. CVRWQCB draft staff report: "Review of Selenium Concentrations in Wetland Water Supply Channels in the Grassland Watershed," May 2000

   A review of the potential causes of elevated selenium levels in wetland supply channels in the Grassland Watershed and management activities to reduce selenium discharges to these channels was undertaken by the Regional Board and GAF. A supplemental monitoring program was developed with GAF and initiated during WY 1999 to better identify suspected inflows of selenium.

4. CVRWQCB draft staff reports

   a. "Agricultural Drainage Contribution to Water Quality in the Grassland Watershed of the Western Merced, California, October 1998-September 1999 (Water Year 1999)"

   b. "Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis: October 1998 - September 1999 (Water Year 1999)"

   The two CVRWQCB technical reports document the water quality measurements for WY 1999. Comparable annual data reports for have been published by the CVRWQCB since 1986.

5. USGS scientific report

   "Forecasting Selenium Discharges to the San Francisco Bay-Delta Estuary: Ecological Effects of a Proposed San Luis Drain Extension", USGS Open-File Report 00-416, U.S. Geological Survey, Menlo Park, CA, 2000, 358 pages.

Monitoring Program

The monitoring plan outlines the processes for collecting data to determine if the terms and conditions of the GBP are being met. Changes were made to the GBP monitoring program during the year. Those changes are documented within each of the following technical chapters. Major changes included the deletion of water quality sampling on the San Joaquin River at Hills Ferry (Station H) and the deletion of analyzing for dissolved selenium at Stations A and B. Flow, water quality, sediment, biota, and toxicity data are collected to assess the Project impacts (Table 3). The data gathered from this effort allow evaluation of the degree to which the commitments of the UA, EA, Supplemental EA, FONSI, and Appendix A of the UA are being met.

Figure 2. Schematic Diagram Showing Locations of GBP Monitoring Sites Relative to Major Hydrologic Features of the Study Area

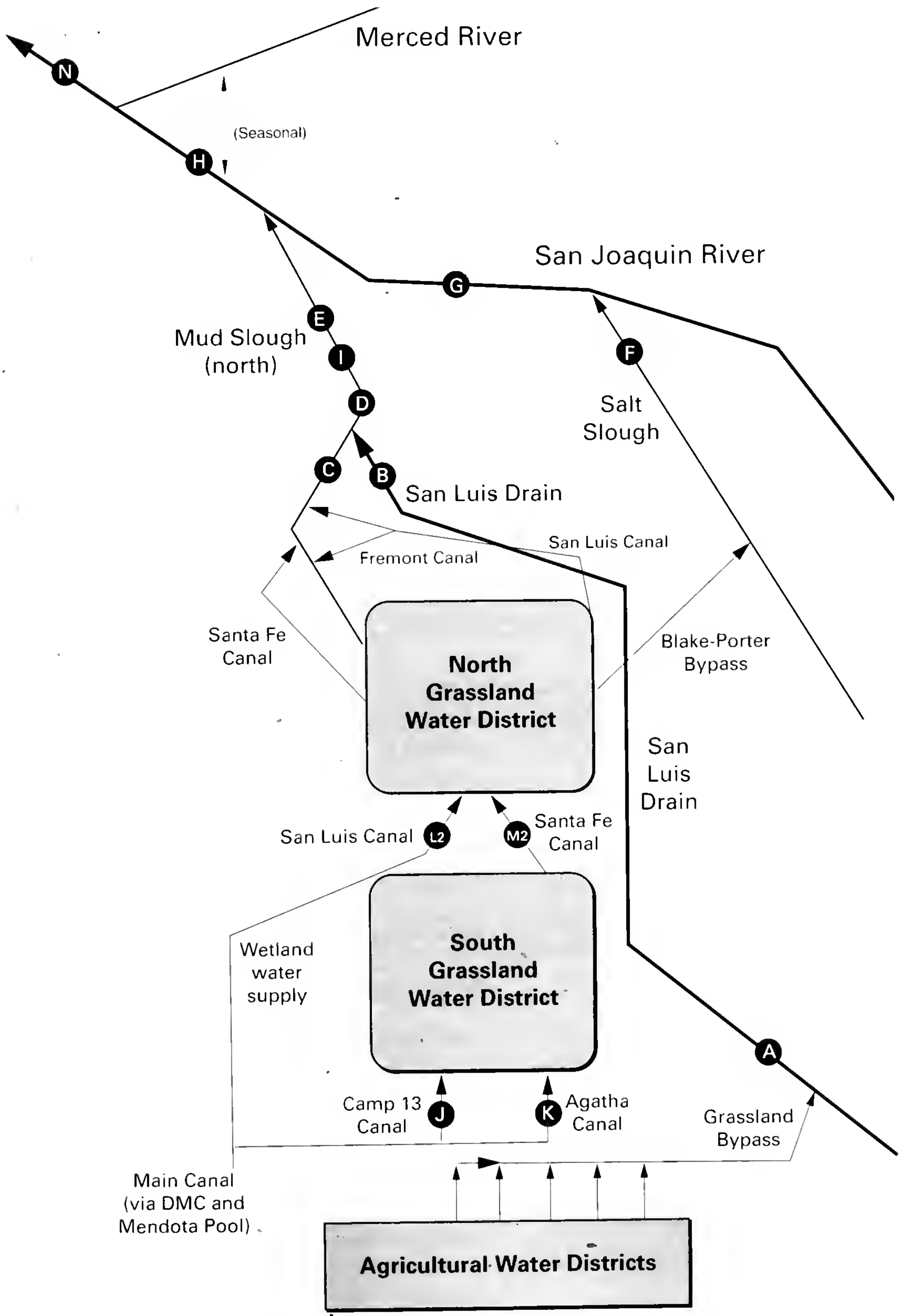


Table 1. Monthly Selenim Discharges into Mud Slough (Station B) Compared to Load Values (Pounds), Water Years 1997, 1998, 1999, 2000.

Month	WY 2000 Discharge	Year 4 Load Values	WY 1999 Discharge	Year 3 Load Values	WY 1998 Discharge	Year 2 Load Values	WY 1997 Discharge	Year 1 Load Values
October	181	348	277	348	248	348	202	348
November	193	348	226	348	207	348	252	348
December	236	389	239	389	178	389	285	389
January	285	479	284	506	355	533	688 **	533
February	541	779	609	823	1,315 *	866	926 ***	866
March	761	959	799	1,013	1,600	1,066	1,119	1,066
April	549	719	529	759	1,554	799	1,280	799
May	427	599	482	633	1,371	666	849	666
June	439	539	524	569	807	599	611	599
July	425	539	462	569	615	599	428	599
August	324	480	418	506	500	533	348	533
September	242	350	275	350	388	350	109	350
12-month total	4,603	NA	5,124	NA	9,118	NA	7,097	NA
Annual load value	NA	5,994	NA	6,327	NA	6,660	NA	6,660

* includes 350 pounds of selenium discharged through the wetland channels due to storm events
** includes 89 pounds of selenium discharged through the wetland channels due to storm events
*** includes 48 pounds of selenium discharged through the wetland channels due to storm events

Water Quality Monitoring on the San Joaquin River at Hills Ferry

As reported in the 3rd Annual Report, the CVRWQCB dropped the Hills Ferry water quality sampling station. Since the station is used for biological monitoring, an agreement was worked out between USFWS and SLDMWA to continue water quality monitoring in order to aid potential future development of revised criteria. The SLDMWA agreed to perform the sampling. Starting in September 2000, the SLDMWA performed the weekly water quality sampling. The SLDMWA does not necessarily follow the sampling protocol outlined in the Program QAPP for collection of water samples for selenium analyses. The data will be presented and reviewed in the biological chapter to reflect the purpose of its collection in the 5th and final Annual Report next year. Listed below are the only data for the 4th Project year: October data are from the CVRWQCB and the September data are from the SLDMWA.

Weekly water quality data continue to be collected by the SLDMWA for the 5th and final year of the Project. Water quality data since October 1, 2000 from Hills Ferry is available in the monthly reports as well as the quarterly data summaries.

Data Source	Date	Specific Conductance µS/cm	Selenium ug/L	Boron mg/L
CVRWQCB	10/07/1999	1,380	3.9	1.2
CVRWQCB	10/14/1999	1,530	2.7	1.3
CVRWQCB	10/21/1999	1,280	1.9	1.0
CVRWQCB	10/28/1999	1,420	2.5	1.0
no data collected from November 1, 1999 through August 31, 2000				
SLDMWA	09/01/2000	1,520	8.1	1.5
SLDMWA	09/08/2000	1,580	8.2	1.8
SLDMWA	09/13/2000	1,250	5.3	1.0
SLDMWA	09/21/2000	1,560	6.9	1.3

Project Organization

The GBP involves the coordination and cooperation of several state and federal agencies whose authority, interests, or activities directly overlap in one or more aspects of the GBP. These agencies include USBR, USFWS, USGS, USEPA, CVRWQCB, CDFG and the SLDMWA. The latter organization includes local drainage and water districts that participate in the drainage activities. The Grassland Area Farmers (GAF) formed a regional drainage entity under the umbrella of the SLDMWA.

Table 2. Grassland Bypass Project Selenium Load Levels (Pounds)

Month	Year 1-2	Year 3	Year 4	Year 5
October	348	348	348	348
November	348	348	348	348
December	389	389	389	389
January	533	506	479	453
February	866	823	779	736
March	1,066	1,013	959	906
April	799	759	719	679
May	666	633	599	566
June	599	569	539	509
July	599	569	539	509
August	533	506	480	453
September	350	350	350	350
12-month total[1]	7,096	6,813	6,528	6,246
Annual load Levels	6,660[2]	6,327[3]	5,994[4]	5,661[5]

1. The 12-month total for any given year is somewhat higher than the annual load target for that year because the monthly targets for the months of September, October, November and December have been adjusted to allow for greater selenium discharge than would typically occur. This adjustment has been made to provide greater selenium management flexibility during months when the assimilative capacity of the river is sufficient to sustain this greater load.

2. The 2nd year annual load target is based on the average annual loads discharged over a 9-year historical period (1986-1994), which includes both wet and dry year data, as well as full and partial water supply data. It is divided by month based on the average historical distribution of selenium loads except where the Total Maximum Monthly Load (TMML) calculation (using a 1-in-5 month violation rate) allows for a greater monthly load.

3. The 3rd year annual load target is based on a 5% reduction of the average historical loads. The 5% reduction is applied equally across all months except where the TMML (using a 1-in-5 month violation rate) allows for greater monthly selenium loads.

4. The 4th year annual load target is based on a 10% reduction of the average historical loads. The 10% is applied equally across all months except where the TMML (using a 1-in-5 month violation rate) allows for greater monthly selenium loads.

5. The 5th year annual load target is based on a 15% reduction from the average historical load. The 15% is applied equally across all months, except where the TMML (using a 1-in-5 month violation rate) allows for greater monthly selenium loads.

Oversight Committee (OC)

The Oversight Committee is comprised of senior level representatives from USBR, USFWS, CDFG, CVRWQCB, and USEPA. The role of the OC is to review process and assure performance of all operations of the GBP, including monitoring data, compliance with selenium load reduction goals, and other relevant information. The OC makes recommendations to the GAF, USBR, and the CVRWQCB, as appropriate, regarding all aspects of the GBP. This includes modifications to Project operations, appropriate mitigative actions, and termination of the Agreement, if necessary. The OC also carries out functions required of it under the UA which include determining the occurrence and extent of load exceedances, the amount of the drainage incentive fees that are payable, and actions or programs to be funded by the incentive fees.

The OC meets in a public forum, as needed, to review the status, progress, and monitoring results of the

Figure 3a: Grassland Bypass Project Water Year 2000
Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values

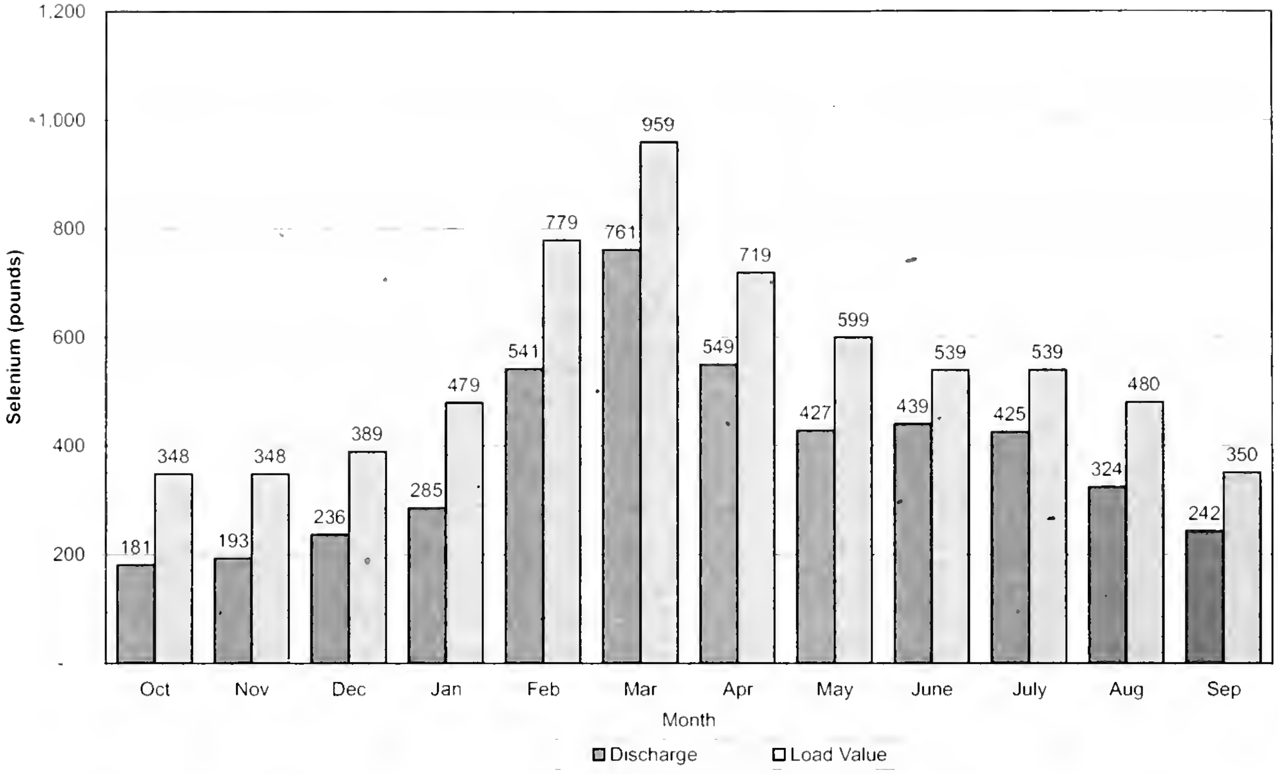


Figure 3b: Grassland Bypass Project Water Year 1999
Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values

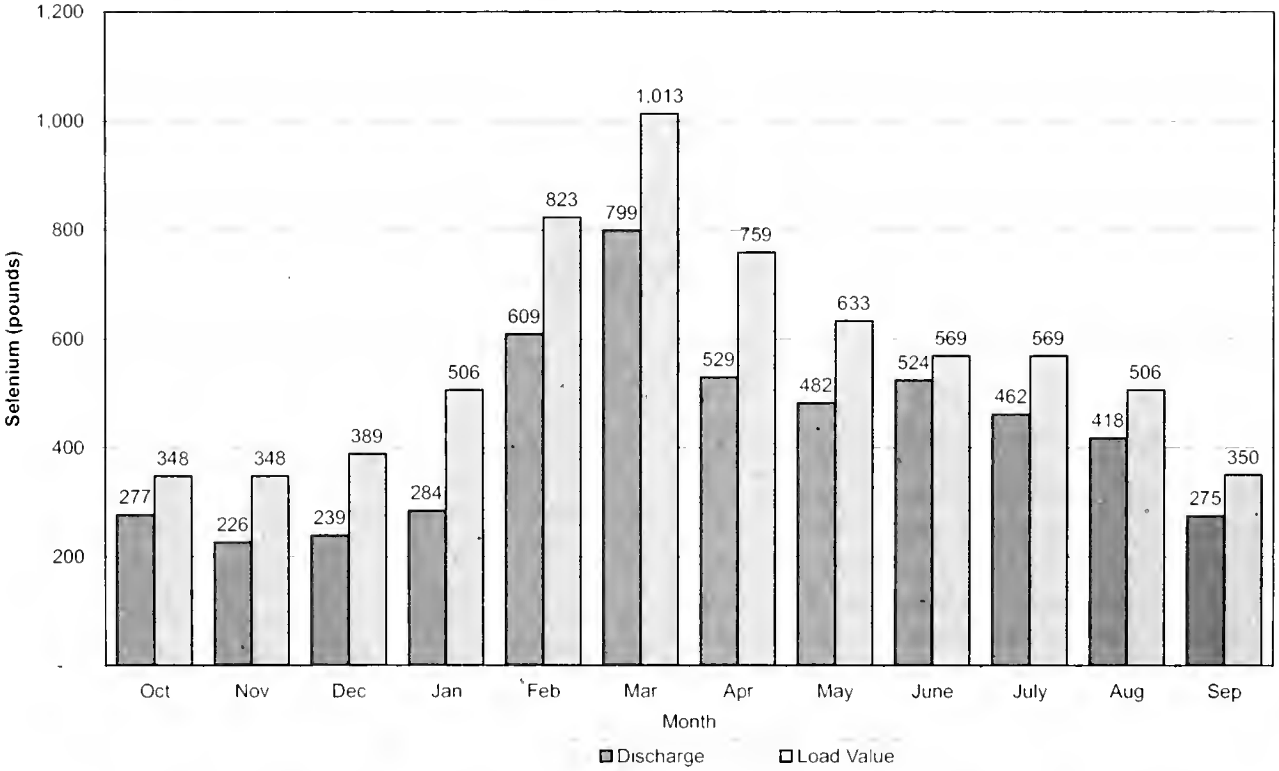


Table 3. Monitoring Stations, Parameters, and Frequencies

STATION		PHYSICAL					CHEMICAL		SEDIMENT	BIOTA	TOXICITY
		Flow	Temp	pH	EC	TSS	Se	B	Bed Se	Se	In-lab
San Luis Drain	A	C	W	W	W	W	W	W	Q		
	B	C	C	W	C	W	D	W	Q		M
	checks 1-2								A		
	checks 10-11								A		
	checks 14-15								A		
	checks 17-18								A		
Mud Slough	C		W	W	W		W	W	Q	Q	M
	D	C	C	W	C		W	W	Q	Q	M
	E								Q	Q	
	I		A	A	A		A	A	A	A	
Salt Slough	F	C	C	W	C		W	W	Q	Q	M
Wetland Channels	J	W	W	W	W		W	W			
	K	W	W	W	W		W	W			
	L2	W	W	W	W		W	W			
	M2	W	W	W	W		W	W			
San Joaquin River	G		W	W	W		W	W		Q	
	H (discontinued for WY 2000)									Q	
	N	C	C	W	C		D	W			

KEY
C = continuous
D = daily
W = weekly
M = monthly
Q = quarterly
A = annually

GBP. The OC considers findings and recommendations from the TPRT and other subcommittees. The OC also considers input and recommendations from the SLDMWA and other key stakeholders.

Technical and Policy Review Team (TPRT)

The Grassland Bypass Project Oversight Committee formed the TPRT to serve as staff to the OC. The TPRT consists of a representative from CVRWQCB, CDFG, USBR, USFWS, and USEPA, plus a member from USGS serving as an independent technical advisor. The TPRT is responsible for obtaining and providing the necessary information, developing alternatives, and formulating recommendations to the OC. This includes producing or overseeing the production of any analytical and interpretive reports, and obtaining appropriate peer or scientific review as necessary. The TPRT is responsible for coordinating, evaluating, and recommending associated research and investigation needs as the GBP proceeds. The TPRT works closely with the DCRT, described below, and with approval of the OC, may designate and utilize additional subcommittees or task groups as needed to accomplish specific tasks or responsibilities.

Data Collection and Reporting Team (DCRT)

The Data Collection and Reporting Team consists of the agency representatives and contractors responsible for data collection and reporting. The DCRT is responsible for coordinating monitoring activities, identifying and resolving any issues involving data collection and reporting, and making recommendations for revision of data collection and reporting procedures to the TPRT. The DCRT prepared the monitoring plan as well as the associated Quality Assurance Project Plan (QAPP) (Entrix, Inc., 1997). The DCRT met monthly during the first three years of operation and met quarterly during the fourth year.

Figure 3c: Grassland Bypass Project Water Year 1998
Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values

Note February value includes 350 pounds of selenium discharged through wetland channels due to storm

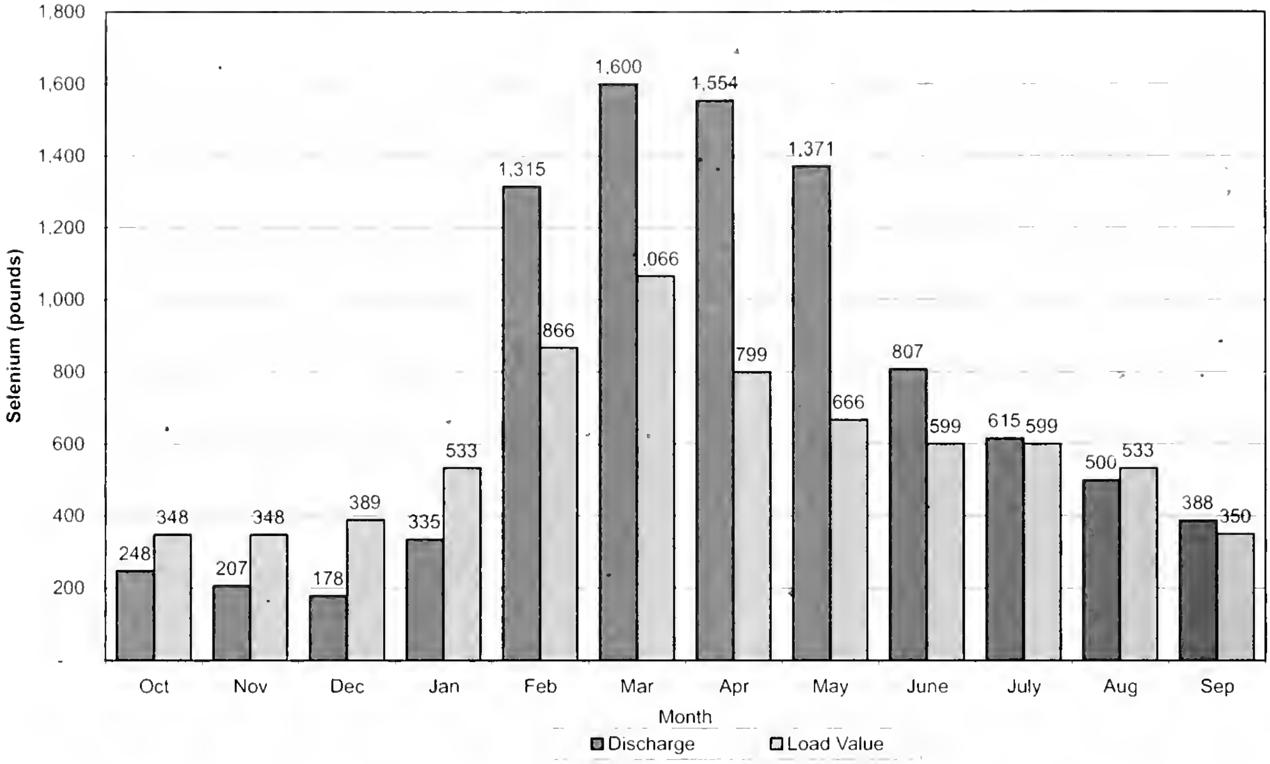
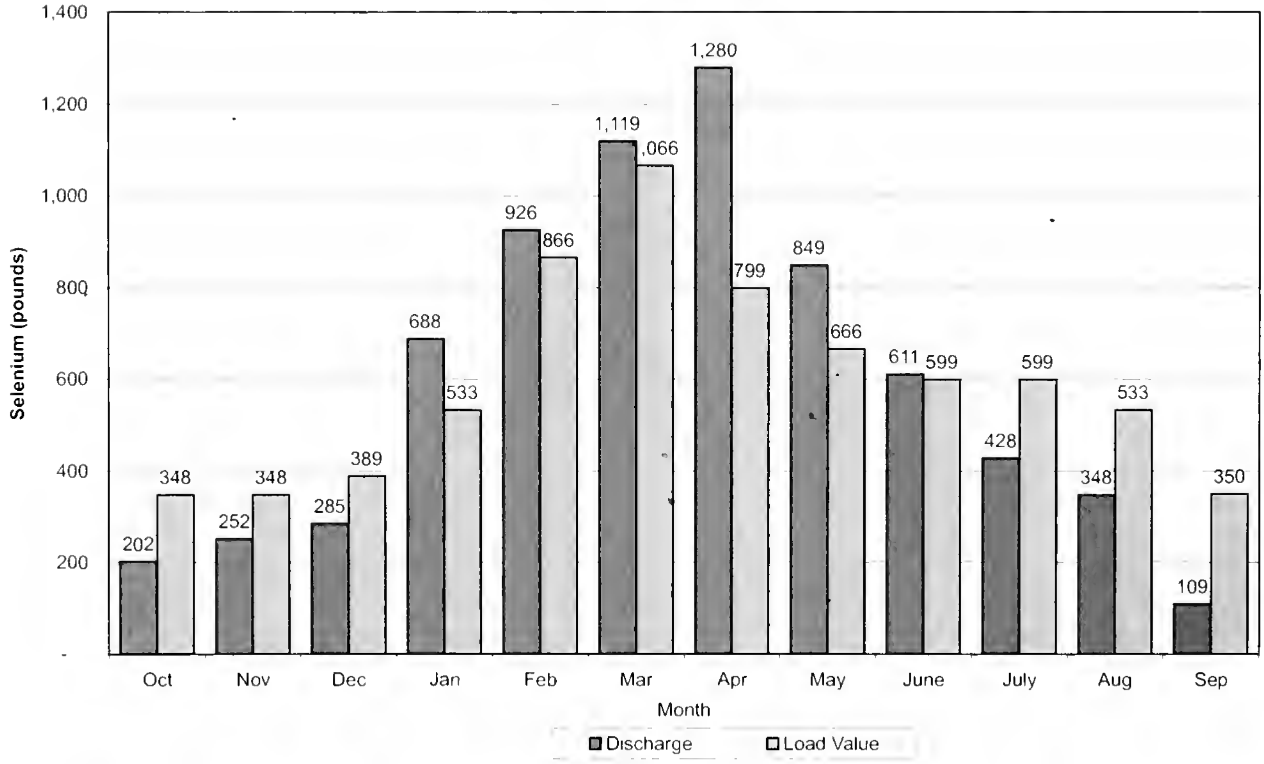


Figure 3d: Grassland Bypass Project Water Year 1997
Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values

Note: January value includes 89 pounds of selenium discharged through wetland channels due to storm events
Note: February value includes 48 pounds of selenium discharged through wetland channels due to storm events



Data Management

Each agency collecting data is responsible for its own internal data quality and management procedures. These are detailed in the QAPP. In addition, each agency submits its data to the San Francisco Estuary Institute (SFEI) for compiling and reporting.

Reporting

The San Francisco Estuary Institute (SFEI) assembles, summarizes, and distributes monthly, quarterly and annual reports. Monthly and quarterly data reports consist of primary data from the 14 key monitoring stations as depicted in Table 3: SLD (A, B), Mud Slough (C, D, E, I), Salt Slough (F), wetland channels (J, K, L2, M2), and the San Joaquin River (G, H, N). The monthly report presents data collected during that particular month, including the calculated selenium load discharged at Station B, the terminus of the SLD. Quarterly data reports consist of all available data from all stations during a 3-month period. SFEI also prepares quarterly narrative and graphical summaries of the most recent Project data. The focus of SFEI is to report data and information from all sampling sites in a timely manner. All reports are distributed to the participating parties and are available to the public upon request.

A web site for the GBP provides current reports describing Project results. Also available are pre-Project information, related scientific studies, photographs of many of the stations, and other related topics. Visit the GBP Web site by first connecting to USBR Mid-Pacific Region's home page at <http://www.mp.usbr.gov/> and then select <Projects> and then select <Grassland Bypass Project>.

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Joseph C. McGahan,
Drainage Coordinator

Introduction

The Grassland Bypass Project is an innovative program that was designed to improve water quality in the channels used to deliver water to wetland areas. Prior to the Project, subsurface drainage water was conveyed through those channels en route to the San Joaquin River. This limited the availability of these wetland channels to deliver high-quality habitat water supplies. The Project consolidates subsurface drainage flows on a regional basis and utilizes a portion of the federal San Luis Drain to convey the flows around the habitat areas (Figure 1).

The Grassland Area Farmers (GAF) formed a regional drainage entity in March 1996 under the umbrella of the San Luis and Delta-Mendota Water Authority to implement the Grassland Bypass Project. Participants include the Broadview Water District, Charleston Drainage District, Firebaugh Canal Water District, Pacheco Water District, Panoche Drainage District, Widren Water District, and the Camp 13 Drainers (an association of landowners located in part of Central California Irrigation District). This entity includes approximately 97,000 gross acres of irrigated farmland on the west side of the San Joaquin Valley, referred to as the Grassland Drainage Area (GDA). The area is highly productive, producing an estimated $113 million annually in agricultural crop market value, with an additional estimated $126 million generated for the local and regional economies, for a total estimated economic value of $239 million.

In order to meet the selenium load limits, the Grassland Area Farmers (GAF) have implemented a wide variety of practices which include: formation of a regional drainage entity, newsletters and other communications with the farmers, a monitoring program, an active land management program to utilize subsurface drainage on salt tolerant crops, use of State Revolving Fund loans for improved irrigation systems, use and installation of drainage recycling systems to mix subsurface drainage water with irrigation supplies under strict limits, tiered water pricing, and tradable loads programs. The GAF are also pursuing in-Valley treatment options to reduce drainage discharges and position themselves to meet future salt standards.

Project Improvements and Benefits

In WY 2000 drainage discharge from the drainage area has been reduced when compared to WY 1996, a similar irrigation supply and rainfall year prior to implementation of the GBP. Drainage volume has been reduced 41%, selenium load has been reduced 54%, salt load has been reduced 29%, and boron load has been reduced 14%.

The environmental benefits of the Project are significant to wetland areas including state and federal refuges. Some of the benefits are as follows:

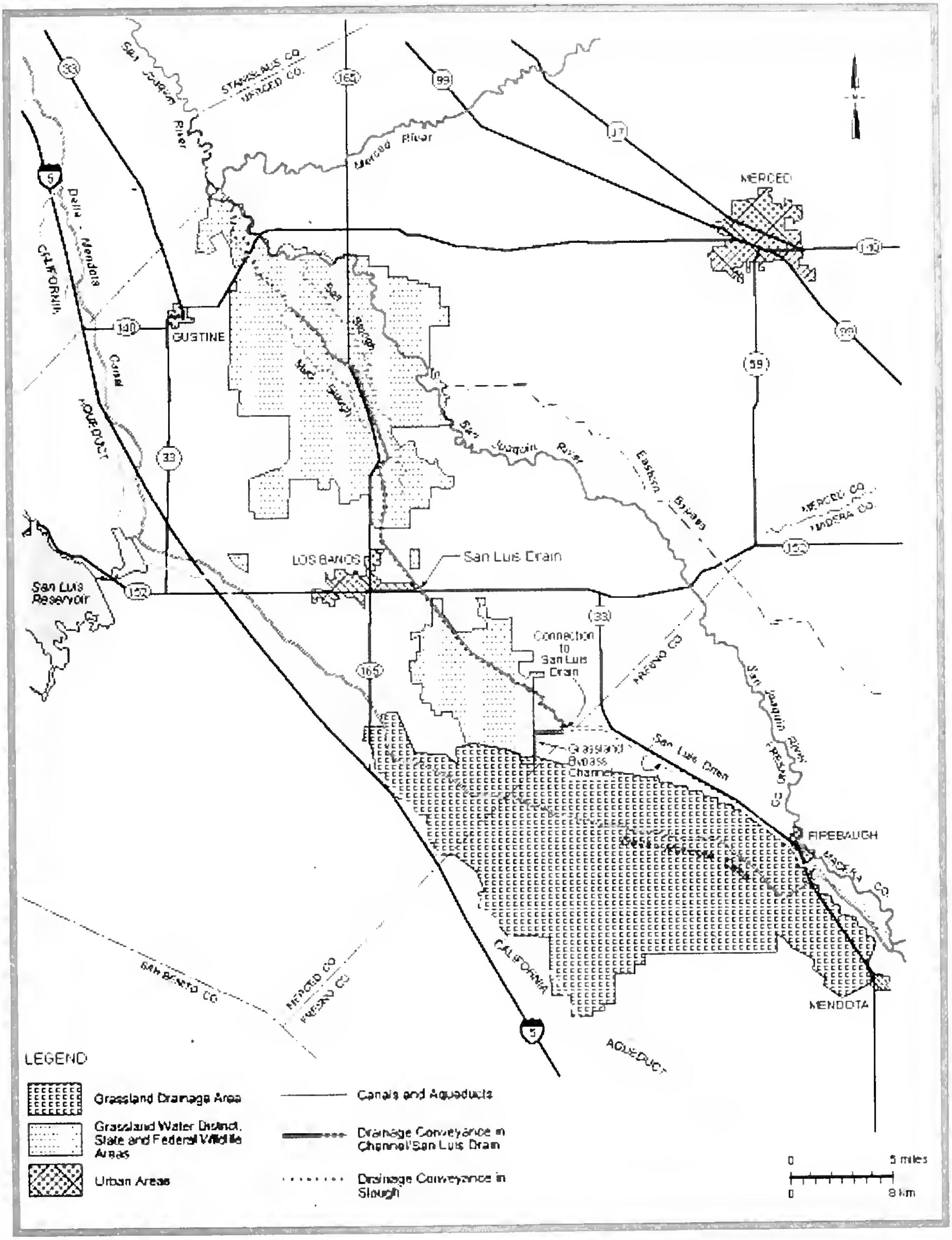
- Conveyance systems are now used solely for the delivery of fresh water to the wetland areas through existing supplies as well as those supplies made available by the Central Valley Project Improvement Act. Drainage water has been removed from conveyance channels totaling 93 miles as follows:

Salt Slough at the San Joaquin River to Mud Slough (South) at Santa Fe Grade	23 Miles
San Luis Canal	15 Miles
Santa Fe Canal	17 Miles
Fremont Canal	9 Miles
Eagle Ditch	4 Miles
Kesterson Ditch	2 Miles
Mud Slough (South)	1 Mile
Agatha Canal	7 Miles
Camp 13 Ditch	6 Miles
Gadwall Canal	5 Miles
Mallard Ditch	3 Miles
Sorsky Ditch	1 Mile
TOTAL	93 Miles

- Good quality water from areas upslope of the Grassland area can be collected and put to use in the Grassland Water District and in the state and federal refuges. Prior to the Project this water was mixed with drainage water and was not usable.
- The existing San Luis Drain is being beneficially used and not allowed to deteriorate.

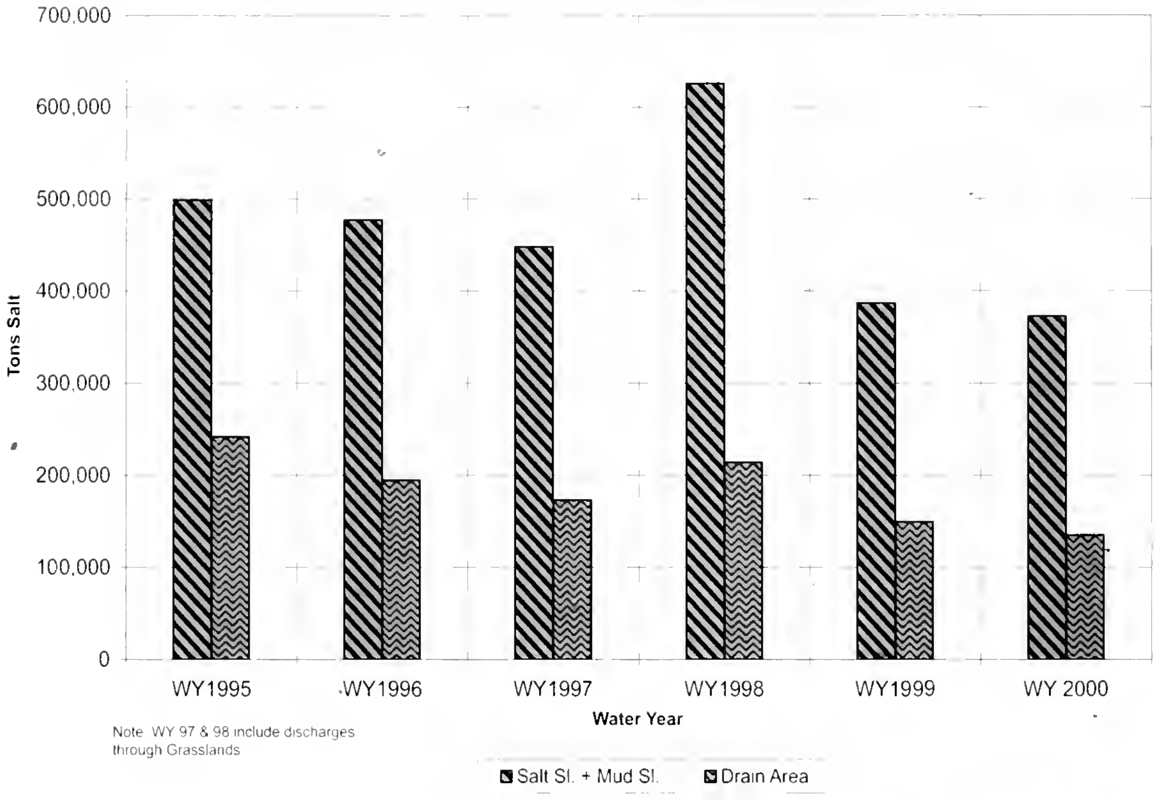
The beneficial uses and habitat along Salt Slough and other channels as noted above have improved. In WY 1996, prior to the Grassland Bypass Project, the mean selenium concentration in Salt Slough at Lander Avenue was 16 parts per billion (ppb). Since the beginning of the Grassland Bypass Project, the 2 ppb monthly mean water quality objective for Salt Slough has been met in 47 of 48 months, including every month in WY 2000. The only month in which objectives were not met

Figure 1. Project Features Map



Source. URS Greiner Woodward Clyde - Oakland

Figure 2. Grassland Basin Salt Load



was February 1998, when uncontrollable flood flows were mixed with subsurface drainage water and could not be contained within the Grassland Bypass Project (that month the monthly mean selenium concentration in Salt Slough was 4 ppb).

In WY 1996 (the year prior to implementation of the GBP), the annual mean selenium concentration at Camp 13 Ditch was 55.9 parts per billion (ppb). In WY 1997, the first year of operation of the Grassland Bypass Project; the annual mean selenium concentration at Camp 13 Ditch was 2.6 ppb. The main goal of the Bypass Project (to remove selenium from wetland channels) was substantially achieved in the first year. In April, 1998, specific actions were taken to eliminate any possible subsurface drainage discharges from the GDA into the Camp 13 Slough. Since that time the monthly mean selenium concentrations have varied from 1.1 ppb to 2.5 ppb. In WY 2000 the concentrations varied from 0.8 ppb to 2.1 ppb, with an annual average of 1.3 ppb.

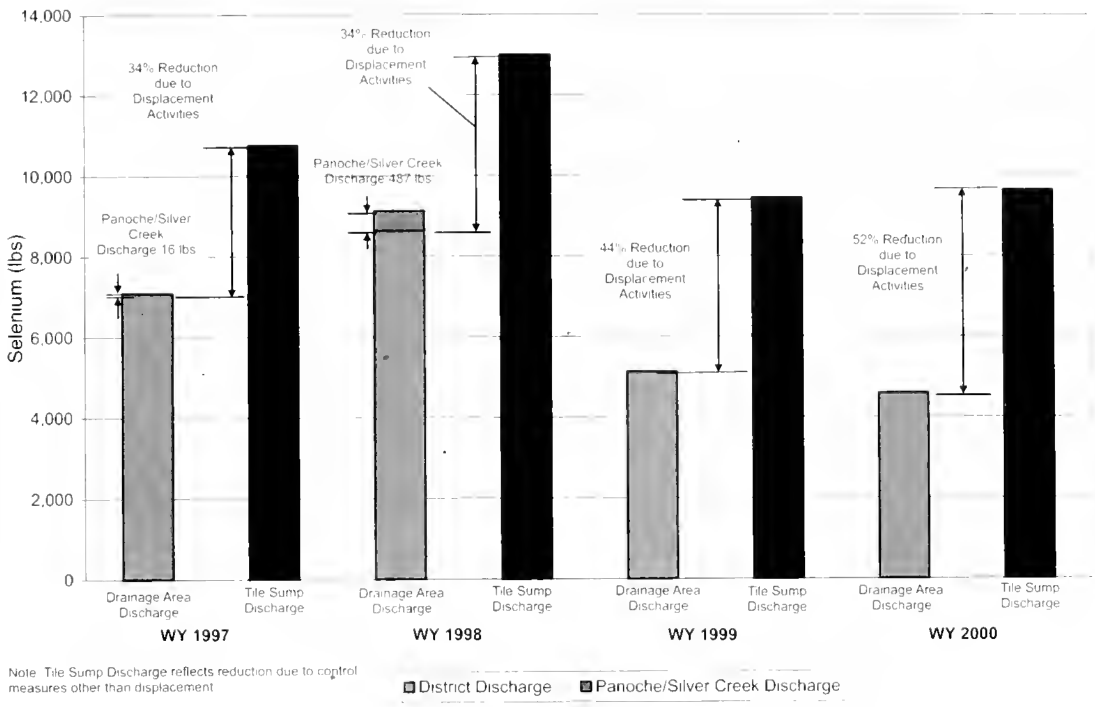
Figure 2 shows the salt discharge from the drainage area compared to the discharge from Salt and Mud Slough for WYs 1995 through 2000. Salt load from the drainage area decreased 29% in WY 2000 compared to WY 1996 (a year with similar water supply and rainfall), and discharge from Mud and Salt Sloughs decreased 24% for the same period.

Drainage Reduction Activities

Components of drainage control activities are shown in Table 1. Each of these activities was described in the WY 1998 GBP Annual Report. The contribution to regional reduction of drainage discharges from each of the individual plan components is difficult to ascertain. On the other hand, the area-wide general progress in control of discharged selenium is demonstrable. Figure 3 shows the subsurface drainage collected from tile drainage systems in WYs 1997, 1998, 1999, and 2000 within the GDA compared to the discharge into the Grassland Bypass Project from the GDA. It can be seen that 34% of the subsurface drainage collected in the tile sumps was prevented from discharging from the area both in WY 1997 and WY 1998, 44% in WY 1999, and 52% in WY 2000.

An estimate has been made of the components of subsurface drainage within the GDA. This information is shown in Figure 4. The subsurface drainage is measured in pounds of selenium. The total amount of drainage discharge was determined based on historic data (WY 1986 to WY 1994) for a year in which there was not excessive rainfall and when there were somewhat normal irrigation supplies. This was also a time before

Figure 3. Grassland Drainage Area Selenium Discharge



Note: Tile Sump Discharge reflects reduction due to control measures other than displacement

conservation and drainage reduction methods were implemented to as full an extent as in WY 1999 and 2000. WY 1987 was chosen as the representative year. Although it was a critical water year on the San Joaquin River, it followed a wet year, and the drainage area received a 100% water supply. In this year the drainage discharge amounted to 11,000 pounds of selenium. Known reduction activities that took place that year amounted to 1,700 pounds for a total quantity of drainage discharge of approximately 12,700 pounds.

The two major categories of drainage reduction are conservation and displacement. Conservation is reduction of drainage water before it exits the subsurface drainage systems. This would include activities such as improved irrigation methods and application, sprinkler pre-irrigations, and institutional measures such as tiered water pricing and tradable loads. Displacement is reduction of drainwater after it leaves the subsurface drainage systems but before it is discharged from the drainage area. It would include such things as drain water recycling, pilot treatment projects, and active land management programs (using drainwater for crop irrigation or other water consumption activities). The amounts attributed to the two components of drainage reduction and river discharge (using WY 1987 as a baseline with 12,700 pounds of total drainage discharge)

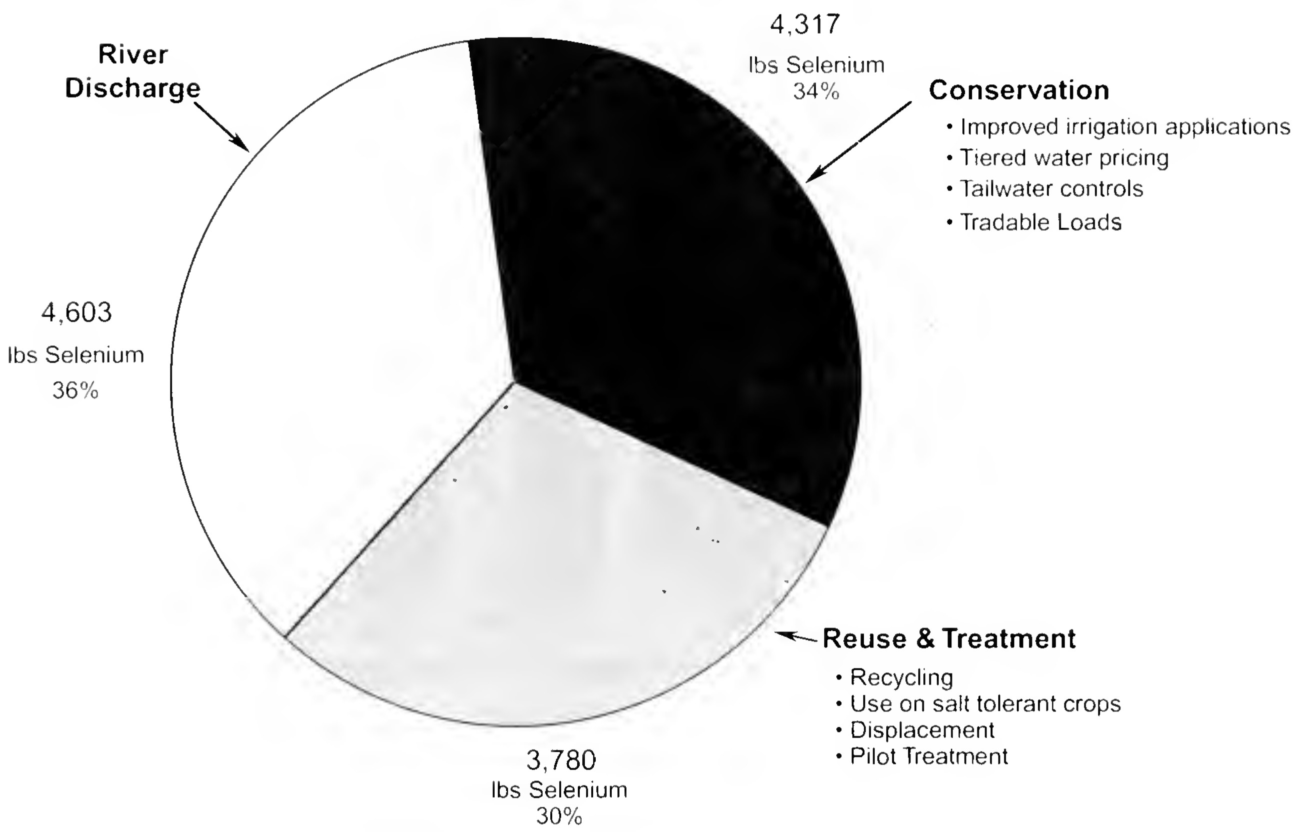
TABLE 1. Components of Short Term Drainage Management Plan

Regional Components
- Regional Drainage Entity (Activity Agreement)
- Regional Drainage Coordinator
- Irrigation and Drainage Workshops
- Regional Newsletter
- Regional Monitoring Program
- Toxicity Testing
- Active Land Management Program
- Economic Incentives Program

District-Level Components
- Low interest water conservation equipment loans
- Tiered water pricing
- Sprinkler pre-irrigations
- Tailwater recirculation
- Sump management (measurement, level manipulation and cycling)
- Drain water recycling
- Drain water displacement projects
- Drain water treatment
- Limited water transfers

Farm-Level Components
- Improved irrigation methods and application
- Tailwater return ponds
- On-farm recycling

Figure 4. Components of Subsurface Drainage Reduction (lbs selenium) Values for WY 2000, Percentages Compared to Historic Amounts (1987)



are conservation (4,320 pounds or 34%), displacement (3,780 pounds or 30%) and river discharge (4,603 pounds or 36%).

In-Valley Drainage Program

The first phase of an In-Valley Disposal Program will be implemented in WY 2001. Funds provided from Proposition 13 allowed for purchase of 4,000 acres of land within the GDA and for planting of salt tolerant crops and some facility improvements to deliver drainage water to the crops for irrigation. A portion of this land had already been used for this purpose in WY 1999 under the active land management program. This Project will ultimately allow for planting and irrigation of the entire 4,000 acres with drainage water. Future phases call for installing subsurface drainage systems, implementing treatment, and salt disposal components.

In order to plan for future phases of the In-Valley Program, a cooperative effort is underway between the GAF, the California Department of Water Resources and the U. S. Bureau of Reclamation. This effort will investigate key design components of the Project including economic impacts.

Future Year Load Limits

The Grassland Area Farmers successfully met monthly and annual load limits in water year 2000. The total selenium discharge in WY 2000 was 4,603 pounds. Annual load limits in year 5 of the GBP reduce 5% per year from 5,994 pounds in WY 2000 to 5,661 pounds in WY 2001. The annual amount in WY 2000 is less than the year 5 load limit. In addition, all of the year 5 monthly limits would have been met in WY 2000.

Flow and Salinity Monitoring

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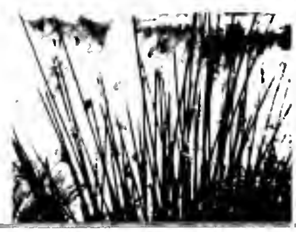
GRASSLAND BYPASS



PROJECT

Summary

Flow and salinity measurements were taken to monitor the effects of the Grassland Bypass Project (GBP) on the San Luis Drain (SLD), Mud Slough, Salt Slough, and the San Joaquin River. The U.S. Geological Survey (USGS) operated four monitoring stations, and the San Luis & Delta-Mendota Water Authority (SLDMWA) operated one station. The California Regional Water Quality Control Board, Central Valley Region (CVRWQCB), measured the salinity of water quality samples collected at these six sites and six other sites where flow is not measured (G, H, J, K, L2, and M2). The San Francisco Estuary Institute (SFEI) compiled this information in monthly and quarterly reports.

Table 1 is a summary of sampling methods at the six stations.

Tables 2–7 summarize monthly flow, salinity, and salt loads at six locations during the four years of the Project. Note that historical salinity and load values have been updated and differ from those in the WY 1999 annual report and errata sheets.

The data record for WY 2000 is complete for all stations. Flow and salinity sensors performed properly at all stations with a few problems. Minor vandalism occurred at the Crows Landing station. At Station B, algae continued to harm the EC probes operated by the USGS. Mats of vegetation lifted EC probes out of the water at Stations D and F. Algae and mud accretion caused problems with electrical conductivity probes at Stations B and D. Telemetry at these sites has helped to lessen data loss, since problems were diagnosed in the office and corrective measures initiated before traveling to them.

Figure 1 shows the pattern of rainfall and discharge from the 97,000 acre Grassland Drainage Area (GDA) during WY 2000. During the WY 2000, rainfall events occurred during February, March, April, and June. Peak flow for WY 2000 was 77 cfs, well below the capacity of the SLD. No drain water was discharged from the Project into wetland water supply channels during WY 2000.

The GBP conveyed approximately 31,300 acre-feet of drainage water and about 135,000 tons of salt from the GDA in the San Luis Drain during WY 2000.

Flow and Salinity Measurements

The flow of water passing a point is expressed in terms of volume and time: cubic feet per second or acre-feet per day/month/year. There are various methods for measuring flow.

Table 1. Flow and Salinity Monitoring Methods

Station	Agency	Parameter	Sample frequency	Comparable CVRWQCB Site (b)	EC to TDS Factor
A	SLDMWA	Flow	Continuous	San Luis Drain terminus	
	SLDMWA	EC	Continuous	terminus	0.74 (*)
B	USGS	Flow	Continuous	San Luis Drain terminus	
	USGS	EC	Continuous	terminus	0.74 (*)
	CVRWQCB	EC	Daily composite of six samples		
C		Flow	Derived (a)	Salt Slough	
	CVRWQCB	EC	Weekly grab		0.68
D	USGS	Flow	Continuous	Mud Slough	
	USGS	EC	Continuous		0.69
F	USGS	Flow	Continuous	Salt Slough	
	USGS	EC	Continuous		0.68
N	USGS	Flow	Continuous	San Joaquin River	
	USGS	EC	Continuous	at Patterson	0.62
	CVRWQCB	EC	Daily composite of six samples		

(a) Flow passing Station C is calculated as difference between flows at Stations D and B.
(b) CVRWCB, 1998. Page 15: San Luis Drain factor revised 10 2000.
(*) San Luis Drain factor revised October 2000.

The salinity of water is estimated by measuring electrical conductivity (EC), which is the ability of a solution to pass an electric current. Current is carried by inorganic anions such as chloride, nitrate, sulfate, and phosphate ions dissolved in the solution, as well as cations like sodium, calcium, magnesium, iron, and aluminum. Total dissolved solids (TDS) is a lab procedure that measures the mass of solids in a solution. The CVRWQCB has calculated factors to convert EC to TDS.

The method for determining flow-weighted concentrations and calculating loads of salt are explained in CVRWQCB, 1998 (pp. 4–8).

Station A

Location	San Luis Drain Check 17, near Dos Palos, California (USGS 11262890) (CVRWQCB MER562)
Responsibility	San Luis & Delta-Mendota Water Authority (Summers Engineering)
Parameters	Stage, electrical conductivity, temperature
Equipment	Sharp-crested weir, stilling well with a Stevens recorder and shaft encoder, staff gauge, weir stick; electrical conductivity/temperature sensor; data logger, telephone and modem; Sigma autosampler.

Description

Station A is located near South Dos Palos, California. Its purpose is to measure the volume and quality of GDA drainwater as it enters the San Luis Drain.

Data Summary

Table 2 and Figure 2 summarize the flow and salinity of water that passed Station A during the four years of the Project.

During WY 2000, the total volume of drainage water that passed the site was 29,350 acre-feet. The average flow that passed Station A was 40.5 cubic feet per second (cfs). The flow reached a maximum of 74 cfs on April 18, 2000. The flow-weighted EC of water that passed the site was about 4,478 microSiemens per centimeter (µS/cm), with a brief peak on March 29, 2000 of 5,970 µS/cm. The load of salt discharged from the Grassland Drainage Area was about 129,400 tons during WY 2000.

The total volume of water discharged during WY 2000 was similar to that discharged during WY 1999. However, the load of salt discharged was about 10% less than WY 1999.

Figure 1. Daily Rainfall and Discharge from the Grassland Bypass Project

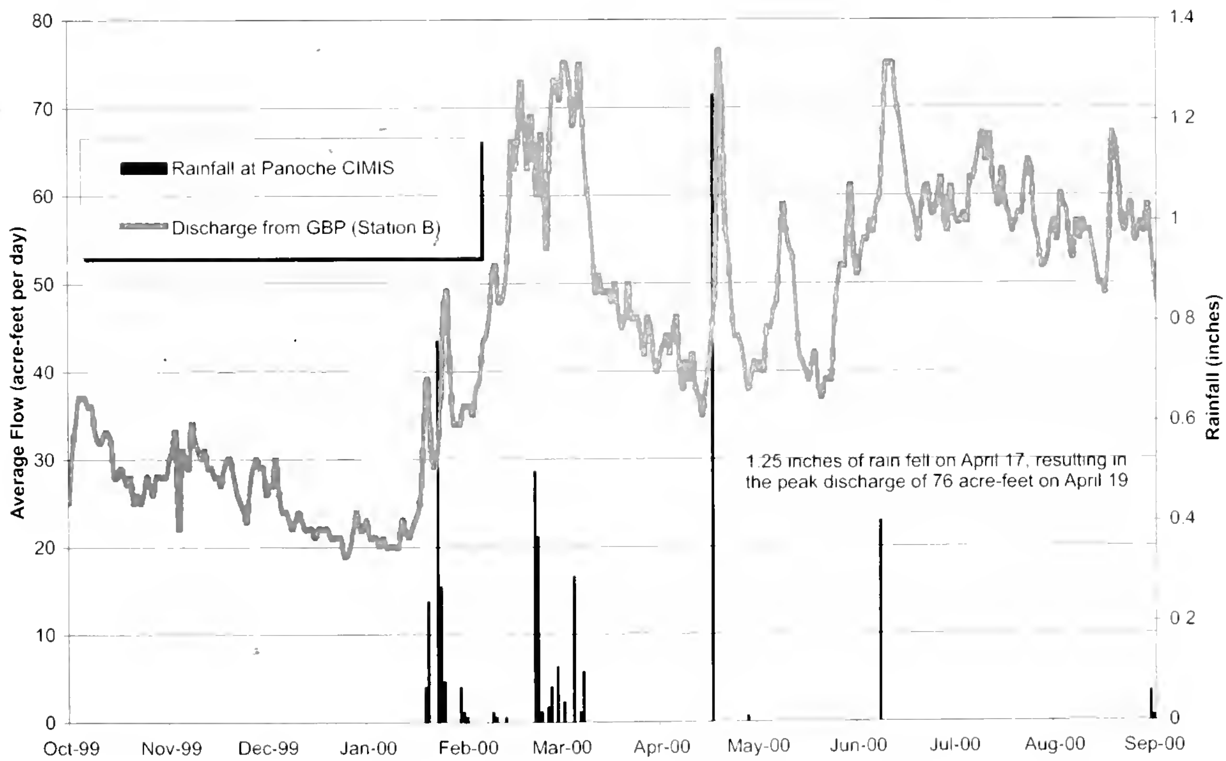


Table 2. Monthly Flow and Salinity of Water Entering the San Luis Drain (Station A), WY 1997–2000

	Flow				Salinity					
	Mean daily cfs		Total acre-feet		FW EC µS/cm		TDS mg/L	Salt load tons		
Oct-1996	22.0	L	1,350	L	4,326	Rr	3,201	5,877	Rr
Nov-1996	24.2	L	1,437	L	3,812	Rr	2,821	5,513	Rr
Dec-1996	29.6	L	1,818	L	4,775	Rr	3,534	8,737	Rr
Jan-1997	62.2	L	3,827	L	4,804	Rr	3,555	18,503	Rr
Feb-1997	78.4	L	4,356	L	5,256	Rr	3,889	23,042	Rr
Mar-1997	83.5	L	5,131	L	4,628	Rr	3,425	23,898	Rr
Apr-1997	77.6	L	4,619	L	5,391	Rr	3,989	25,060	Rr
May-1997	69.9	L	4,301	L	4,654	Rr	3,444	20,145	Rr
Jun-1997	54.6	L	3,251	L	4,823	Rr	3,569	15,780	Rr
Jul-1997	53.0	L	3,257	L	4,217	Rr	3,121	13,823	Rr
Aug-1997	49.7	L	3,055	L	3,722	Rr	2,754	11,443	Rr
Sep-1997	23.3	L	1,384	L	3,311	Rr	2,450	4,612	Rr
Oct-1997	21.7	L	1,335	L	5,065	Rr	3,748	6,805	Rr
Nov-1997	16.7	L	994	L	4,640	Rr	3,434	4,642	Rr
Dec-1997	17.4	L	1,070	L	5,016	Rr	3,712	5,401	Rr
Jan-1998	20.0	L	1,230	L	5,393	Rr	3,991	6,676	Rr
Feb-1998	123.0	L	6,833	L	3,200	Rr	2,368	22,006	Rr
Mar-1998	115.1	L	7,075	L	4,599	Rr	3,403	32,746	Rr
Apr-1998	91.5	L	5,444	L	4,914	Rr	3,636	26,923	Rr
May-1998	76.7	L	4,714	L	4,952	Rr	3,664	23,493	Rr
Jun-1998	61.0	L	3,629	L	5,109	Rr	3,781	18,659	Rr
Jul-1998	73.8	L	4,538	L	4,408	Rr	3,262	20,132	Rr
Aug-1998	62.6	L	3,849	L	4,267	Rr	3,158	16,529	Rr
Sep-1998	47.7	L	2,839	L	3,938	Rr	2,914	11,252	Rr
Oct-1998	27.6	G	1,700	G	4,972	Gr	3,679	8,506	Gr
Nov-1998	20.4	G	1,210	G	5,371	Gr	3,975	6,541	Gr
Dec-1998	18.6	G	1,140	G	5,268	Gr	3,898	6,044	Gr
Jan-1999	22.7	G	1,390	G	5,010	Gr	3,707	7,008	Gr
Feb-1999	54.8	G	3,040	G	4,687	Gr	3,468	14,340	Gr
Mar-1999	52.3	G	3,220	G	5,363	Gr	3,969	17,379	Gr
Apr-1999	35.9	G	2,140	G	5,511	Gr	4,078	11,869	Gr
May-1999	48.7	G	3,000	G	4,973	Gr	3,680	15,014	Gr
Jun-1999	60.9	G	3,620	G	4,581	Gr	3,390	16,689	Gr
Jul-1999	64.8	G	3,990	G	4,230	Gr	3,130	16,986	Gr
Aug-1999	64.1	G	3,940	G	3,648	Gr	2,700	14,465	Gr
Sep-1999	34.9	G	2,080	G	4,234	Gr	3,133	8,863	Gr
Oct-1999	18.9	S	1,162	S	5,423	Rr	4,013	6,341	Rr
Nov-1999	21.4	S	1,273	S	4,693	Rr	3,473	6,010	Rr
Dec-1999	16.5	S	1,015	S	4,853	Rr	3,591	4,957	Rr
Jan-2000	20.8	S	1,281	S	4,158	Rr	3,077	5,359	Rr
Feb-2000	53.4	S	3,074	S	4,554	Sr	3,370	14,089	Sr
Mar-2000	52.3	S	3,217	S	5,051	Sr	3,738	16,353	Sr
Apr-2000	43.9	S	2,614	S	4,669	Sr	3,455	12,283	Sr
May-2000	47.3	S	2,906	S	4,150	Sr	3,071	12,137	Sr
Jun-2000	63.6	S	3,783	S	4,269	Sr	3,159	16,253	Sr
Jul-2000	61.9	S	3,804	S	4,017	Sr	2,973	15,378	Sr
Aug-2000	58.3	S	3,586	S	3,669	Sr	2,715	13,241	Sr
Sep-2000	27.5	S	1,637	S	4,230	Sr	3,130	6,967	Sr

	average	totals	average	average	totals
WY 1997	52.3	37,786	4,477	3,313	176,433
WY 1998	60.6	43,550	4,625	3,423	195,263
WY 1999	42.1	30,470	4,821	3,567	143,705
WY 2000	40.5	29,350	4,478	3,314	129,368

References

- G U.S. Geological Survey published data
- Gr Flow-weighted average calculated from USGS 15 minute EC data
- L Lawrence Berkeley Laboratory 15 minute flow and EC data
- Rr Flow-weighted average calculated from Regional Board lab EC data
- S San Luis & Delta-Mendota Water Authority
- Sr Flow-weighted average calculated from SLDMWA 15 minute flow and EC data

- EC Electrical conductivity
- FW Flow-weighted average concentration
- TDS Total dissolved solids

Performance

All equipment performed as required at this site, and there were no major gaps in data due to malfunction. EC was measured in weekly grab samples during October 1999 through January 2000. Continuous EC measurements were taken for February 2000 through September 2000.

Comments

The SLDMWA operated this station during WY 2000. A new footbridge was constructed in November 2000 for staff to safely take measurements and collect samples from the middle of the drain.

Station B

Location	San Luis Drain, near Gustine, California (USGS 11262895, CVRWQCB MER535)
Responsibility	US Geological Survey (flow, EC, temp), CVRWQCB (EC, water quality)
Parameters	Stage, velocity, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure sensor, 2 - acoustic velocity meters, monthly current meter readings, 2 - EC/temperature sensors, data logger, telephone and modem.

Description

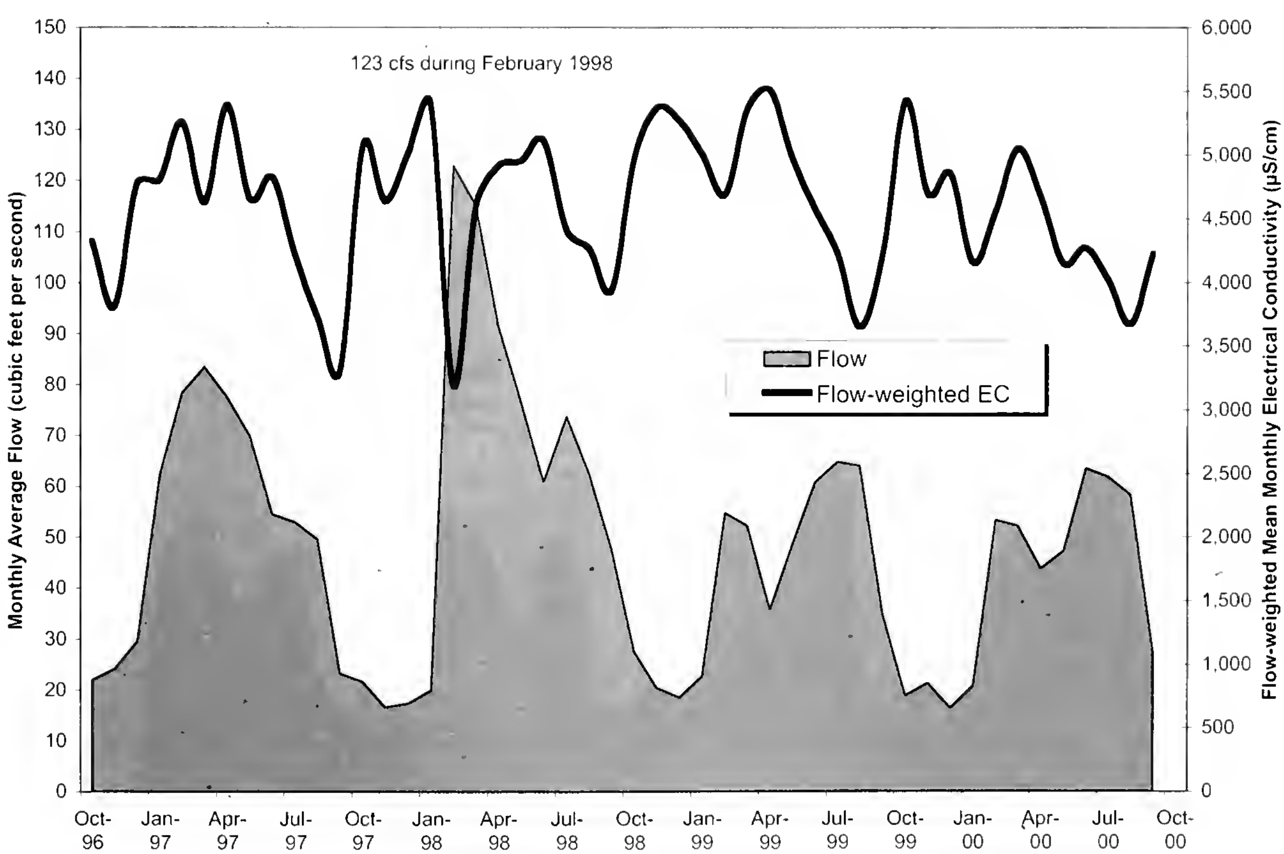
Station B is located about 28 miles northwest of Station A, about 2 miles from the terminus of the Drain. It is the primary site for measuring the flow and selenium load discharged from the GDA into Mud Slough. The performance of the GBP to manage flows and selenium loads is assessed at this site.

Data Summary

Table 3 and Figure 3 summarize the flow and salinity of water that passed Station B during the four years of the Project.

During WY 2000, the average flow that passed Station B was 43 cfs. The peak flow of 76 cfs occurred on April 19, 2000, one day after a similar peak at Station A. The total volume of drainage water that passed this site was 31,300 acre-feet.

Figure 2. Flow and Salinity of Water Entering the San Luis Drain (Station A)



EC ranged from 3,160 to 5,750 µS/cm, with a flow-weighted average of 4,301 µS/cm. About 135,000 tons of salt were discharged from the San Luis Drain into Mud Slough.

The total volume of water discharged during WY 2000 was similar to that discharged during the 1999 WY. However, the load of salt discharged was about 10% less than WY 1999.

Performance

The USGS had several problems at this site last year. In June, an EC probe failed because of the growth of microorganisms on it. Less EC data were lost during WY 2000 because of frequent visits to clean the probe. USGS found that if the probe was left in a solution of vinegar for 30 to 60 minutes, most of the organisms were removed, greatly increasing the accuracy of the EC data recorded from visit to visit. There are two EC probes at this station; both were replaced in WY 2000.

There were several periods when the data logger lost power and did not collect data. This was caused by the loss of AC power to the gauge house and the failure of the backup battery system. The backup battery system was replaced and no further loss of data for this reason has occurred.

Between June 10-13, 2000, gauge height record errors were caused when a rodent chewed the orifice line in two. The line was replaced.

There were times when USGS staff could not enter the gauge house because of hundreds of yellow jackets swarming in and outside the gauge. They now get there early in the morning before the hornets warm up.

During WY 2001, USGS will work with the SLDMWA to improve and calibrate flow-monitoring equipment at the terminus of the Drain.

Station C

Location	Mud Slough, approximately 1/2 mile upstream of San Luis Drain terminus (CVRWQCB MER536)
Responsibility	CVRWQCB
Parameters	Electrical conductivity, temperature, pH, boron
Equipment	None. Weekly grab samples are taken here

Figure 3. Flow and Salinity of Water in the San Luis Drain (Station B)

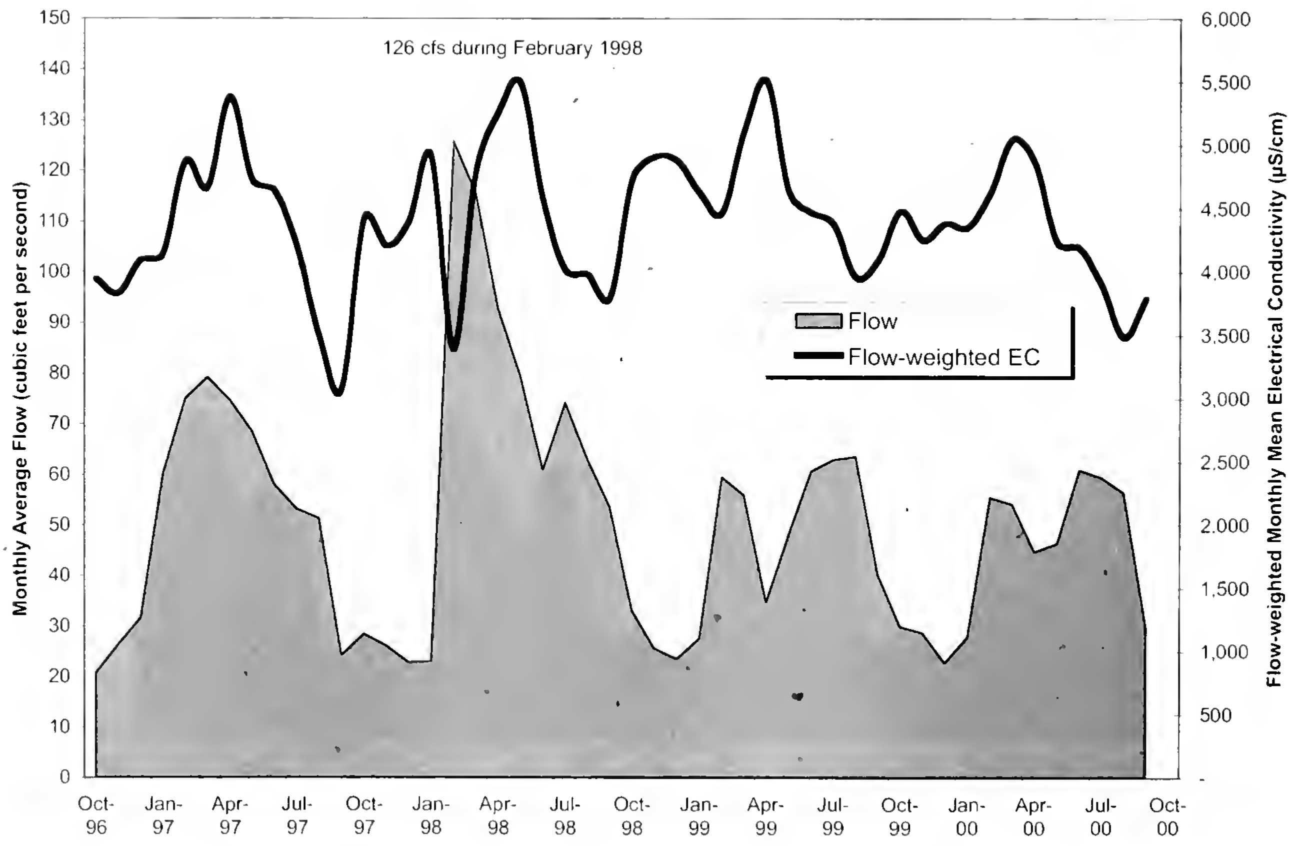


Table 3. Monthly Flow and Salinity of Water in the San Luis Drain (Station B), WY 1997–2000

	Flow				Salinity				
	Mean daily cfs		Total acre-feet		FW EC µS/cm		TDS mg/L	Salt load tons	
Oct-1996	20.8	L	1,276	L	3,948	L	2,922	5,070	Lr
Nov-1996	26.4	L	1,569	L	3,830	L	2,834	6,048	Lr
Dec-1996	31.7	L	1,946	L	4,095	L	3,030	8,020	Lr
Jan-1997	60.2	L	3,703	L	4,142	L	3,065	15,433	Lr
Feb-1997	75.1	L	4,173	L	4,872	L	3,605	20,463	Lr
Mar-1997	79.3	L	4,876	L	4,669	L	3,455	22,913	Lr
Apr-1997	74.8	L	4,453	L	5,380	L	3,981	24,111	Lr
May-1997	68.6	L	4,215	L	4,730	L	3,500	20,063	Lr
Jun-1997	58.1	L	3,457	L	4,642	L	3,435	16,153	Lr
Jul-1997	53.3	L	3,277	L	4,206	L	3,112	13,873	Lr
Aug-1997	51.4	L	3,159	L	3,497	L	2,588	11,117	Lr
Sep-1997	24.3	L	1,445	L	3,077	L	2,277	4,474	Lr
Oct-1997	28.6	L	1,756	L	4,425	L	3,275	7,819	Lr
Nov-1997	26.2	L	1,558	L	4,206	L	3,112	6,594	Lr
Dec-1997	22.9	L	1,406	L	4,398	L	3,255	6,221	Lr
Jan-1998	23.1	L	1,421	L	4,919	L	3,640	7,036	Lr
Feb-1998	125.9	L	6,993	L	3,397	L	2,514	23,906	Lr
Mar-1998	115.6	L	7,106	L	4,788	L	3,543	34,244	Lr
Apr-1998	92.9	L	5,527	L	5,258	L	3,891	29,250	Lr
May-1998	79.5	L	4,890	L	5,494	L	4,066	27,036	Lr
Jun-1998	61.1	L	3,635	L	4,576	L	3,386	16,740	Lr
Jul-1998	74.3	L	4,572	L	4,020	L	2,975	18,494	Lr
Aug-1998	63.1	L	3,883	L	3,983	L	2,947	15,561	Lr
Sep-1998	53.7	L	3,193	L	3,798	L	2,811	12,203	Lr
Oct-1998	33.2	G	2,040	G	4,738	Gr	3,506	9,742	Gr
Nov-1998	25.7	G	1,530	G	4,909	Gr	3,633	7,546	Gr
Dec-1998	23.6	G	1,450	G	4,881	Gr	3,612	7,142	Gr
Jan-1999	27.6	G	1,700	G	4,628	Gr	3,425	7,909	Gr
Feb-1999	59.6	G	3,310	G	4,467	Gr	3,306	14,883	Gr
Mar-1999	56.0	G	3,450	G	5,117	Gr	3,787	17,743	Gr
Apr-1999	34.9	G	2,080	G	5,512	Gr	4,079	11,532	Gr
May-1999	48.2	G	2,960	G	4,637	Gr	3,431	13,830	Gr
Jun-1999	60.7	G	3,610	G	4,471	Gr	3,309	16,252	Gr
Jul-1999	63.0	G	3,870	G	4,380	Gr	3,241	17,068	Gr
Aug-1999	63.6	G	3,910	G	3,960	Gr	2,930	15,596	Gr
Sep-1999	40.3	G	2,400	G	4,094	Gr	3,030	9,890	Gr
Oct-1999	30.0	G	1,850	G	4,482	Gr	3,317	8,329	Gr
Nov-1999	28.8	G	1,710	G	4,253	Gr	3,147	7,334	Gr
Dec-1999	22.8	G	1,400	G	4,383	Gr	3,243	6,177	Gr
Jan-2000	27.9	G	1,720	G	4,355	Gr	3,223	7,520	Gr
Feb-2000	55.5	G	3,190	G	4,622	Gr	3,420	14,844	Gr
Mar-2000	54.2	G	3,330	G	5,047	Gr	3,735	16,916	Gr
Apr-2000	44.8	G	2,660	G	4,863	Gr	3,599	13,037	Gr
May-2000	46.4	G	2,850	G	4,238	Gr	3,136	12,157	Gr
Jun-2000	61.0	G	3,630	G	4,190	Gr	3,101	15,313	Gr
Jul-2000	59.5	G	3,660	G	3,899	Gr	2,885	14,344	Gr
Aug-2000	56.5	G	3,470	G	3,485	Gr	2,579	12,180	Gr
Sep-2000	30.1	G	1,790	G	3,792	Gr	2,806	6,843	Gr

	average	totals	average	average	totals
WY 1997	52.0	37,550	4,257	3,150	167,739
WY 1998	63.9	45,939	4,439	3,284	205,104
WY 1999	44.7	32,310	4,650	3,441	149,133
WY 2000	43.1	31,260	4,301	3,183	134,994

References

- G U.S. Geological Survey published data
- Gr Flow-weighted average calculated from USGS 15 minute EC data
- L Lawrence Berkeley Laboratory 15 minute flow and EC data
- Lr Flow-weighted average calculated from LBL 15 minute EC data

- EC Electrical conductivity
- FW Flow-weighted average concentration
- TDS Total dissolved solids

Description

Station C is located in Mud Slough upstream from the end of the San Luis Drain. Water at this point comes from wetlands in the Grassland Water District (GWD). Data collected at this site are considered a baseline for measuring the impact of the GBP on the slough. The CVRWQCB collected weekly water quality samples here, and the US Fish & Wildlife Service sampled fish and invertebrates four times at this site.

Data Summary

Table 4 and Figure 4 summarize the flow and salinity of water that passed Station C during the four years of the Project. Flow was not measured at this site, but was estimated as the difference between flows passing Stations D and B.

During WY 2000, about 63,000 acre-feet of water passed this site at an average rate of 88 cfs. Flows peaked in late February and early March and diminished in August to less than 25 cfs. The salinity of water at this site was measured by the CVRWQCB in its weekly grab samples. The flow-weighted average EC of water at this site was 1,455 µS/cm. The water was most saline in early May 2000 at 2,620 µS/cm, and diminished to about 700 µS/cm during September 2000. About 84,000 tons of salt in water passed this site during WY 2000.

Station D

Location	Mud Slough near Gustine, California (USGS 11262900) (CVRWQCB MER542)
Responsibility	US Geological Survey (flow, EC, temp), CVRWQCB (EC, water quality)
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station D is located in Mud Slough downstream from the terminus of the SLD.

Figure 4. Flow and Salinity of Water in Mud Slough Upstream of Drainage Discharge (Station C)

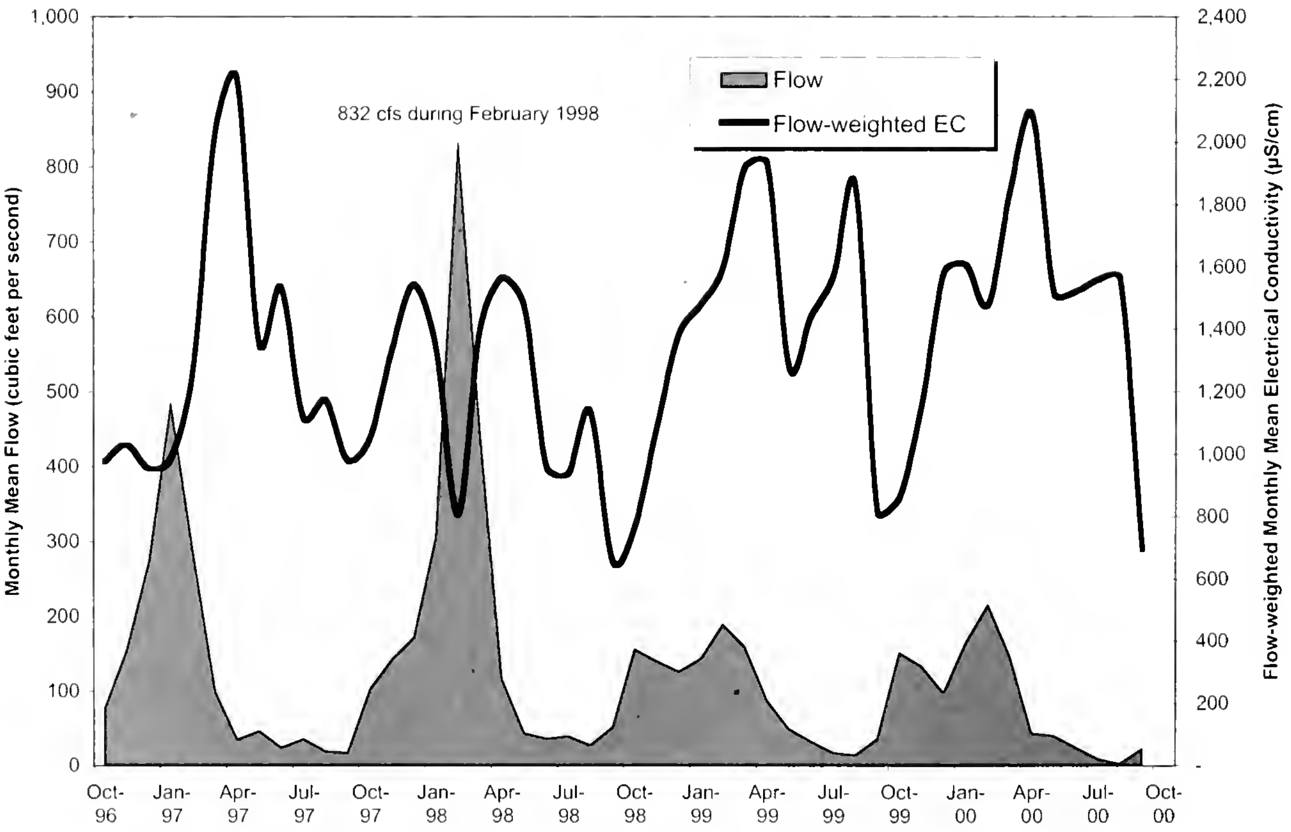


Table 4. Flow and Salinity of Water in Mud Slough Upstream of Drainage Discharge (Station C), WY 1997–2000

	Flow (*)				Salinity				
	Mean daily cfs		Total acre-feet		FW EC µS/cm		TDS mg/L	Salt load tons	
Oct-1996	76.4	Gr	4,704	Gr	975	Rr	663	4,242	Rr
Nov-1996	154.6	Gr	9,181	Gr	1,030	Rr	700	8,745	Rr
Dec-1996	273.3	Gr	16,804	Gr	954	Rr	649	14,825	Rr
Jan-1997	484.8	Gr	29,807	Gr	984	Rr	669	27,124	Rr
Feb-1997	287.9	Gr	16,007	Gr	1,259	Rr	856	18,637	Rr
Mar-1997	98.7	Gr	6,044	Gr	2,026	Rr	1,378	11,324	Rr
Apr-1997	35.2	Gr	2,097	Gr	2,205	Rr	1,499	4,276	Rr
May-1997	46.4	Gr	2,875	Gr	1,357	Rr	923	3,608	Rr
Jun-1997	24.4	Gr	1,453	Gr	1,537	Rr	1,045	2,065	Rr
Jul-1997	35.7	Gr	2,193	Gr	1,116	Rr	759	2,263	Rr
Aug-1997	19.1	Gr	1,181	Gr	1,176	Rr	800	1,284	Rr
Sep-1997	17.3	Gr	1,035	Gr	981	Rr	667	939	Rr
Oct-1997	102.4	Gr	6,304	Gr	1,049	Rr	713	6,116	Rr
Nov-1997	141.8	Gr	8,422	Gr	1,330	Rr	904	10,359	Rr
Dec-1997	171.1	Gr	10,554	Gr	1,543	Rr	1,049	15,060	Rr
Jan-1998	304.9	Gr	18,749	Gr	1,352	Rr	919	23,442	Rr
Feb-1998	832.1	Gr	46,197	Gr	808	Rr	549	34,520	Rr
Mar-1998	447.4	Gr	27,484	Gr	1,400	Rr	952	35,584	Rr
Apr-1998	116.1	Gr	6,923	Gr	1,566	Rr	1,065	10,026	Rr
May-1998	43.5	Gr	2,660	Gr	1,474	Rr	1,002	3,626	Rr
Jun-1998	36.6	Gr	2,175	Gr	961	Rr	653	1,933	Rr
Jul-1998	39.7	Gr	2,408	Gr	937	Rr	637	2,087	Rr
Aug-1998	27.7	Gr	1,697	Gr	1,138	Rr	774	1,786	Rr
Sep-1998	51.3	Gr	3,067	Gr	657	Rr	447	1,863	Rr
Oct-1998	155.8	Gr	9,570	Gr	764	Rr	520	6,762	Rr
Nov-1998	140.3	Gr	8,370	Gr	1,081	Rr	735	8,368	Rr
Dec-1998	126.4	Gr	7,780	Gr	1,385	Rr	942	9,965	Rr
Jan-1999	143.4	Gr	8,820	Gr	1,479	Rr	1,006	12,064	Rr
Feb-1999	189.4	Gr	10,540	Gr	1,598	Rr	1,087	15,576	Rr
Mar-1999	159.0	Gr	9,780	Gr	1,919	Rr	1,305	17,356	Rr
Apr-1999	87.1	Gr	5,160	Gr	1,929	Rr	1,312	9,205	Rr
May-1999	49.3	Gr	3,030	Gr	1,280	Rr	870	3,587	Rr
Jun-1999	32.8	Gr	1,960	Gr	1,441	Rr	980	2,612	Rr
Jul-1999	17.2	Gr	1,060	Gr	1,572	Rr	1,069	1,541	Rr
Aug-1999	14.3	Gr	880	Gr	1,855	Rr	1,261	1,510	Rr
Sep-1999	35.4	Gr	2,100	Gr	817	Rr	556	1,587	Rr
Oct-1999	151.0	Gr	9,280	Gr	857	Rr	583	7,355	Rr
Nov-1999	133.2	Gr	7,920	Gr	1,156	Rr	786	8,467	Rr
Dec-1999	97.2	Gr	5,960	Gr	1,580	Rr	1,074	8,709	Rr
Jan-2000	164.1	Gr	10,060	Gr	1,606	Rr	1,092	14,941	Rr
Feb-2000	215.5	Gr	12,420	Gr	1,478	Rr	1,005	16,976	Rr
Mar-2000	146.8	Gr	9,030	Gr	1,845	Rr	1,255	15,407	Rr
Apr-2000	43.4	Gr	2,590	Gr	2,087	Rr	1,419	4,999	Rr
May-2000	40.1	Gr	2,470	Gr	1,516	Rr	1,031	3,463	Rr
Jun-2000	24.4	Gr	1,450	Gr	1,523	Rr	1,036	2,042	Rr
Jul-2000	8.8	Gr	540	Gr	1,560	Rr	1,061	779	Rr
Aug-2000	2.4	Gr	150	Gr	1,563	Rr	1,063	217	Rr
Sep-2000	22.0	Gr	1,310	Gr	694	Rr	472	841	Rr

	average	totals	average	average	totals
WY 1997	129.5	93,381	1,300	884	99,334
WY 1998	192.9	136,640	1,185	806	146,403
WY 1999	95.9	69,050	1,427	970	90,132
WY 2000	87.4	63,180	1,455	990	84,197

(*) Flow passing Station C is calculated as difference between flows at Stations D and B

References
- EC Electrical conductivity
- FW Flow-weighted average concentration
- Gr Average calculated from USGS 15 minute flow data
- Rr Flow-weighted average calculated from Regional Board lab EC data
- TDS Total dissolved solids

Data Summary

Table 5 and Figure 5 summarize the daily flow and salinity of water that passed Station D during the four years of the Project

During WY 2000, approximately 94,000 acre-feet of water passed this site. The GBP contributed 33% of this flow. The average flow passing Station D was 131 cfs. Peak flow was 362 cfs on February 18, 2000. The flow-weighted average EC of water passing this site was 2,500 µS/cm. Approximately 202,000 tons of salt flowed past this site, 67% coming from the GBP.

Performance

The EC portion of the probe was pulled out of water or fouled, primarily because of vegetation snagging it, for the following periods: 11/2 -11/3, 11/27 -12/1, 1/19-1/23, 2/8, 2/15, 4/17 - 4/19, 6/2 - 6/3, 7/18 and 7/20. The probe failed and produced erroneous values for the periods 3/11- 3/13 and 3/21. The temperature portion was only affected for the period 11/27-12/1, when the entire probe was pulled out of the water by vegetation mats. In the two years prior to this, vegetation did not affect data quality. As in years past, large EC shifts were a result of fouling by mud and aquatic organisms and were generally alleviated by cleaning during site visits; only occasionally was recalibration necessary. The probe was replaced once, on 3/21, after the EC portion was observed to be failing.

Station E

Location	Mud Slough at Highway 140

No flow or salinity measurements were made at this site during WY 2000.

Station F

Location	Salt Slough at Highway 165 near Stevinson, California (USGS 11261100) (CVRWQCB MER531)
Responsibility	US Geological Survey
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station F is where flow and water quality are monitored in Salt Slough. The GBP has removed the GDA's

Figure 5. Flow and Salinity of Water in Mud Slough (Station D)

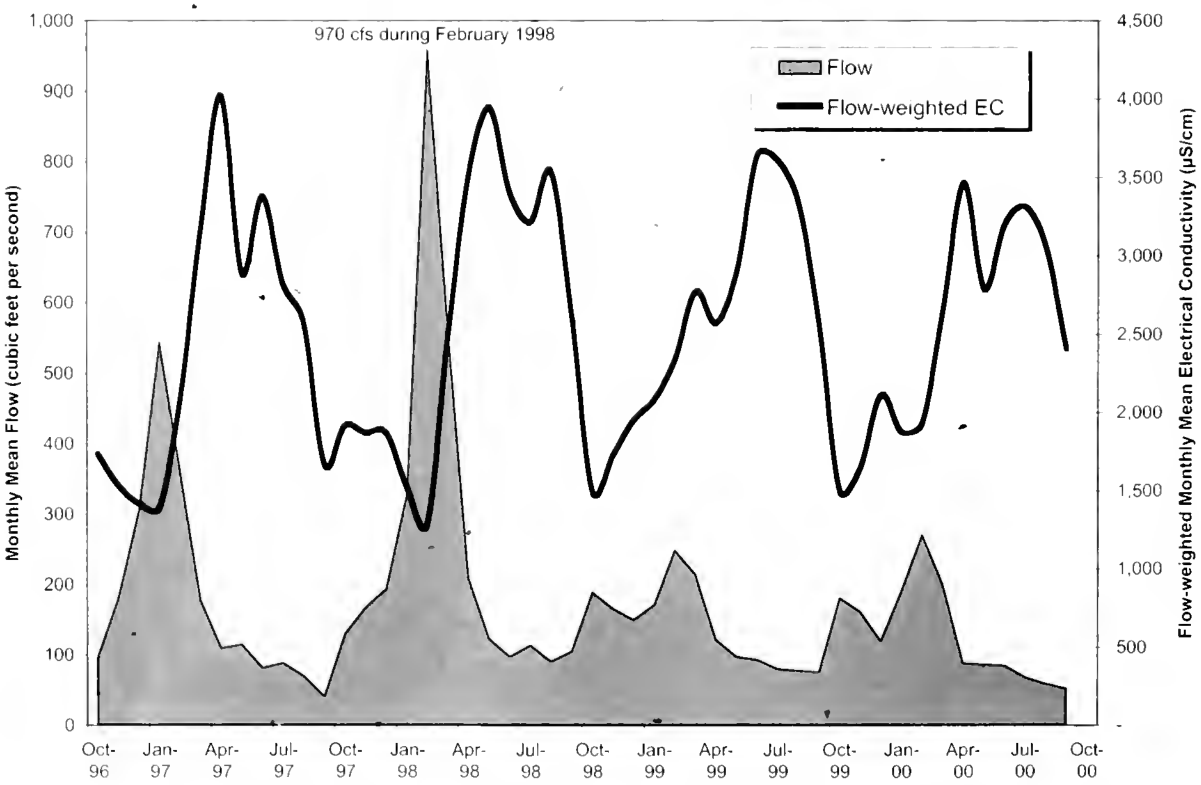


Table 5. Montly Flow and Salinity of Water in Mud Slough (Station D), WY 1997–2000

	Flow				Salinity				
	Mean daily cfs		Total acre-feet		FW EC µS/cm		TDS mg/L	Salt load tons	
Oct-1996	97.2	G	5,980	G	1,738	Gr	1,199	9,748	Gr
Nov-1996	181.0	G	10,750	G	1,536	Gr	1,060	15,496	Gr
Dec-1996	305.0	G	18,750	G	1,418	Gr	978	24,950	Gr
Jan-1997	545.0	G	33,510	G	1,390	Gr	959	43,714	Gr
Feb-1997	363.0	G	20,180	G	2,077	Gr	1,433	39,324	Gr
Mar-1997	178.0	G	10,920	G	3,167	Gr	2,185	32,460	Gr
Apr-1997	110.0	G	6,550	G	4,018	Gr	2,772	24,701	Gr
May-1997	115.0	G	7,090	G	2,891	Gr	1,995	19,227	Gr
Jun-1997	82.5	G	4,910	G	3,378	Gr	2,331	15,555	Gr
Jul-1997	89.0	G	5,470	G	2,819	Gr	1,945	14,475	Gr
Aug-1997	70.5	G	4,340	G	2,576	Gr	1,777	10,483	Gr
Sep-1997	41.6	G	2,480	G	1,672	Gr	1,154	3,887	Gr
Oct-1997	131.0	G	8,060	G	1,916	Gr	1,322	14,493	Gr
Nov-1997	168.0	G	9,980	G	1,873	Gr	1,292	17,530	Gr
Dec-1997	194.0	G	11,960	G	1,873	Gr	1,292	21,011	Gr
Jan-1998	328.0	G	20,170	G	1,526	Gr	1,053	28,880	Gr
Feb-1998	958.0	G	53,190	G	1,289	Gr	889	64,346	Gr
Mar-1998	563.0	G	34,590	G	2,489	Gr	1,717	80,684	Gr
Apr-1998	209.0	G	12,450	G	3,519	Gr	2,428	41,113	Gr
May-1998	123.0	G	7,550	G	3,945	Gr	2,722	27,964	Gr
Jun-1998	97.7	G	5,810	G	3,403	Gr	2,348	18,562	Gr
Jul-1998	114.0	G	6,980	G	3,218	Gr	2,220	21,089	Gr
Aug-1998	90.8	G	5,580	G	3,534	Gr	2,438	18,510	Gr
Sep-1998	105.0	G	6,260	G	2,618	Gr	1,806	15,382	Gr
Oct-1998	189.0	G	11,610	G	1,495	Gr	1,032	16,286	Gr
Nov-1998	166.0	G	9,900	G	1,727	Gr	1,192	16,051	Gr
Dec-1998	150.0	G	9,230	G	1,950	Gr	1,346	16,883	Gr
Jan-1999	171.0	G	10,520	G	2,083	Gr	1,437	20,564	Gr
Feb-1999	249.0	G	13,850	G	2,338	Gr	1,613	30,373	Gr
Mar-1999	215.0	G	13,230	G	2,771	Gr	1,912	34,411	Gr
Apr-1999	122.0	G	7,240	G	2,572	Gr	1,775	17,480	Gr
May-1999	97.5	G	5,990	G	2,900	Gr	2,001	16,314	Gr
Jun-1999	93.5	G	5,570	G	3,644	Gr	2,514	19,032	Gr
Jul-1999	80.2	G	4,930	G	3,608	Gr	2,490	16,689	Gr
Aug-1999	77.9	G	4,790	G	3,334	Gr	2,300	14,980	Gr
Sep-1999	75.7	G	4,500	G	2,558	Gr	1,765	10,808	Gr
Oct-1999	181.0	G	11,130	G	1,498	Gr	1,034	15,642	Gr
Nov-1999	162.0	G	9,630	G	1,647	Gr	1,136	14,885	Gr
Dec-1999	120.0	G	7,360	G	2,109	Gr	1,455	14,570	Gr
Jan-2000	192.0	G	11,780	G	1,874	Gr	1,293	20,724	Gr
Feb-2000	271.0	G	15,610	G	1,931	Gr	1,332	28,291	Gr
Mar-2000	201.0	G	12,360	G	2,653	Gr	1,831	30,773	Gr
Apr-2000	88.2	G	5,250	G	3,463	Gr	2,389	17,056	Gr
May-2000	86.5	G	5,320	G	2,791	Gr	1,926	13,935	Gr
Jun-2000	85.4	G	5,080	G	3,204	Gr	2,211	15,273	Gr
Jul-2000	68.3	G	4,200	G	3,315	Gr	2,287	13,055	Gr
Aug-2000	58.9	G	3,620	G	3,059	Gr	2,111	10,402	Gr
Sep-2000	52.1	G	3,100	G	2,403	Gr	1,658	6,996	Gr

	average	totals	average	average	totals
WY 1997	181	130,930	2,390	1,649	254,022
WY 1998	257	182,580	2,600	1,794	369,564
WY 1999	141	101,360	2,582	1,781	229,871
WY 2000	131	94,440	2,496	1,722	201,601

References

G U.S. Geological Survey published data

Gr Flow-weighted average calculated from USGS 15 minute EC data

EC Electrical conductivity

FW Flow-weighted average concentration

TDS Total dissolved solids

agricultural drainage water from this stream. The water in this channel is derived from wetlands and farmlands outside the GDA area.

Data Summary

Table 6 and Figure 6 summarize the daily flow and EC of water that passed Station F during the four years of the Project.

No water from the GDA was released into Salt Slough during WY 2000. The average flow of water was 195 cfs. The peak flow of 501 cfs occurred on February 16, 2000. Approximately 141,100 acre-feet flowed past this site during WY 2000.

The flow-weighted average EC of water was 1,300 µS/cm, ranging from 654 to 2,280 µS/cm. The total salt load was 171,000 tons.

The total volume of water in Salt Slough during WY 2000 was about 7% less than WY 1999. However, the load of salt in the water was similar to the salt load in WY 1999 due to an 8% increase in average electrical conductivity.

Performance

The EC portion of the probe was pulled partially out of the water by vegetation for the period 9/4 - 9/7, rendering errors. Again, this had not been a source of concern the previous two years. As in the case of Site D, large EC shifts were generally reduced by cleaning during site inspections; recalibration was only necessary one time. Temperature data were complete for the year at this site and data quality was good. No vandalism of the probe occurred this year.

Comments

The California Department of Water Resources also measures flow at this site. The USGS has used this data for comparison and to replace missing values.

Station N

Location	San Joaquin River at Crows Landing, California (USGS 11274550) (CVRWQCB STC504)
Responsibility	US Geological Survey (flow, EC, temp), CVRWQCB (EC, water quality)

Figure 6. Flow and Salinity of Water in Salt Slough (Station F)

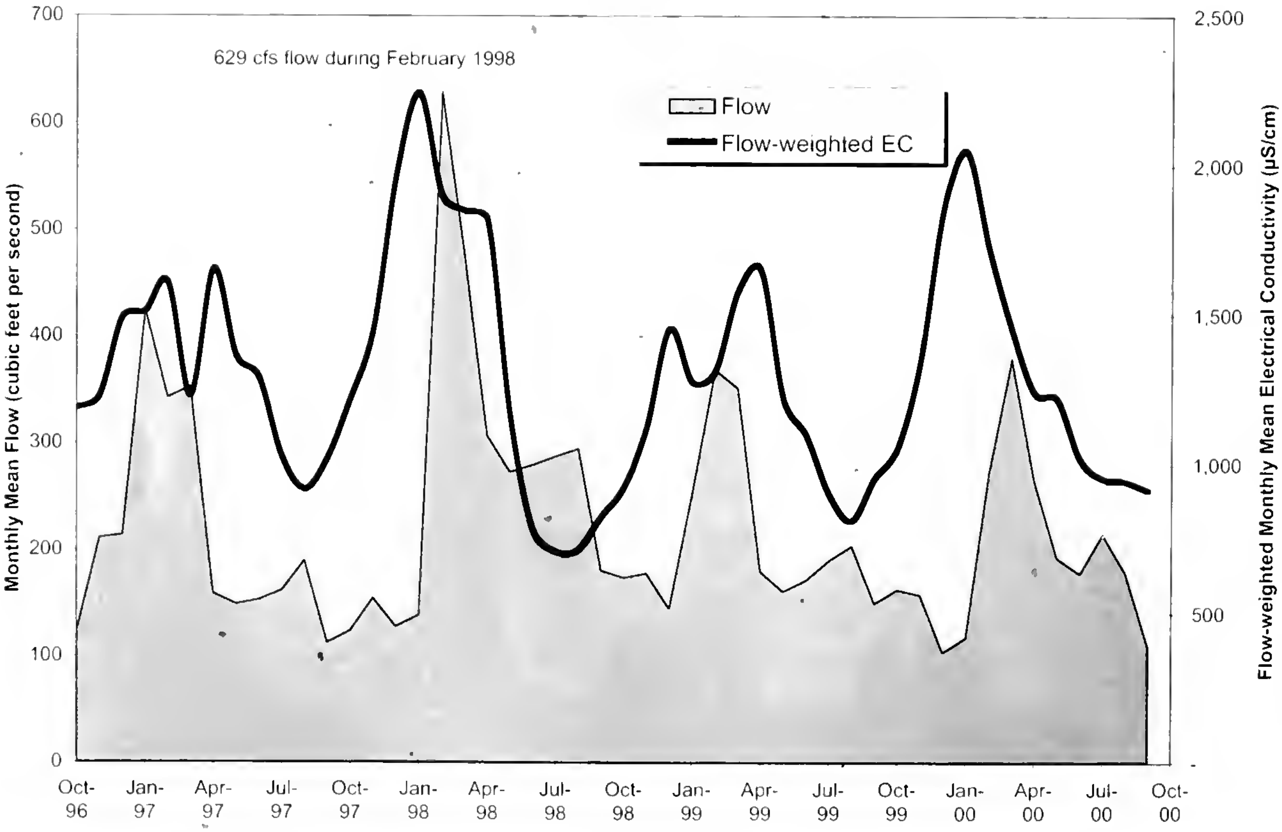


Table 6. Monthly Flow and Salinity of Water in Salt Slough (Station F), WY 1997–2000

	Flow				Salinity				
	Mean daily cfs		Total acre-feet		FW EC µS/cm		TDS mg/L	Salt load tons	
Oct-1996	123	G	7,590	G	1,188	Gr	808	8,342	Gr
Nov-1996	211	G	12,550	G	1,228	Gr	835	14,256	Gr
Dec-1996	214	G	13,140	G	1,490	Gr	1,013	17,831	Gr
Jan-1997	426	G	26,160	G	1,511	Gr	1,027	36,560	Gr
Feb-1997	343	G	19,050	G	1,608	Gr	1,093	28,323	Gr
Mar-1997	353	G	21,720	G	1,233	Gr	838	24,764	Gr
Apr-1997	159	G	9,450	G	1,653	Gr	1,124	14,445	Gr
May-1997	149	G	9,140	G	1,363	Gr	927	11,523	Gr
Jun-1997	153	G	9,130	G	1,292	Gr	879	10,903	Gr
Jul-1997	162	G	9,940	G	1,029	Gr	700	9,459	Gr
Aug-1997	190	G	11,690	G	919	Gr	625	9,929	Gr
Sep-1997	113	G	6,720	G	1,020	Gr	694	6,335	Gr
Oct-1997	124	G	7,680	G	1,220	Gr	830	8,668	Gr
Nov-1997	155	G	9,320	G	1,449	Gr	985	12,486	Gr
Dec-1997	128	G	7,940	G	1,970	Gr	1,340	14,466	Gr
Jan-1998	139	G	8,700	G	2,242	Gr	1,525	18,028	Gr
Feb-1998	629	G	35,030	G	1,901	Gr	1,293	61,588	Gr
Mar-1998	476	G	29,420	G	1,850	Gr	1,258	50,326	Gr
Apr-1998	307	G	18,420	G	1,817	Gr	1,236	30,946	Gr
May-1998	273	G	16,840	G	1,165	Gr	792	18,148	Gr
Jun-1998	280	G	16,800	G	781	Gr	531	12,128	Gr
Jul-1998	288	G	17,930	G	708	Gr	481	11,740	Gr
Aug-1998	295	G	17,250	G	714	Gr	486	11,391	Gr
Sep-1998	181	G	10,770	G	824	Gr	560	8,208	Gr
Oct-1998	174	G	10,720	G	925	Gr	629	9,165	Gr
Nov-1998	178	G	10,570	G	1,123	Gr	764	10,974	Gr
Dec-1998	145	G	8,930	G	1,454	Gr	989	11,999	Gr
Jan-1999	253	G	15,490	G	1,276	Gr	868	18,274	Gr
Feb-1999	369	G	20,490	G	1,311	Gr	891	24,841	Gr
Mar-1999	352	G	21,620	G	1,580	Gr	1,074	31,584	Gr
Apr-1999	180	G	10,730	G	1,652	Gr	1,123	16,396	Gr
May-1999	161	G	9,890	G	1,219	Gr	829	11,143	Gr
Jun-1999	172	G	10,270	G	1,098	Gr	747	10,430	Gr
Jul-1999	190	G	11,680	G	901	Gr	613	9,735	Gr
Aug-1999	204	G	12,520	G	811	Gr	551	9,387	Gr
Sep-1999	150	G	8,860	G	954	Gr	649	7,817	Gr
Oct-1999	163	G	10,010	G	1,054	Gr	717	9,752	Gr
Nov-1999	158	G	9,410	G	1,346	Gr	915	11,712	Gr
Dec-1999	104	G	6,410	G	1,856	Gr	1,262	11,010	Gr
Jan-2000	118	G	7,280	G	2,049	Gr	1,393	13,800	Gr
Feb-2000	272	G	15,670	G	1,724	Gr	1,172	24,979	Gr
Mar-2000	380	G	23,410	G	1,454	Gr	989	31,474	Gr
Apr-2000	265	G	15,770	G	1,241	Gr	844	18,099	Gr
May-2000	193	G	11,840	G	1,219	Gr	829	13,350	Gr
Jun-2000	178	G	10,600	G	1,019	Gr	693	9,991	Gr
Jul-2000	215	G	13,190	G	953	Gr	648	11,626	Gr
Aug-2000	179	G	10,990	G	944	Gr	642	9,595	Gr
Sep-2000	110	G	6,470	G	913	Gr	621	5,463	Gr

	average	totals	average	average	totals
WY 1997	216	156,280	1,295	880	192,670
WY 1998	273	196,100	1,387	943	258,123
WY 1999	211	151,770	1,192	811	171,743
WY 2000	195	141,050	1,314	894	170,851

References

G U.S. Geological Survey published data

Gr Flow-weighted average calculated from USGS 15 minute EC data

EC Electrical conductivity

FW Flow-weighted average concentration

TDS Total dissolved solids

Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station N is located at Crows Landing on the San Joaquin River, a few miles downstream of the tributary of the Merced River.

Data Summary

Table 7 and Figure 7 summarize the mean daily flow and EC of water that passed Station N during the four years of the Project.

During WY 2000, the average flow that passed this site was about 1,420 cfs. The maximum flow of 6,610 cfs occurred on March 3, 2000. The total amount of water that passed this site was about 1,027,500 acre-feet. The discharge from the GBP was about 3% of this flow. The flow-weighted average EC of water that passed Station N was 976 µS/cm. The load of salt in the water was about 704,000 tons. The discharge from the GBP was about 19% of the salt load measured at this site.

Performance

Data quality from both the EC and temperature portions of the probe was generally good, except for the period from 5/3 - 5/16, when the probe was pulled from the water, presumably by vandals. Data at this site has historically been good, with minimal fouling or failure of the EC/temperature sensors. Regular cleaning alleviated large shifts; one recalibration of the EC sensor was necessary during the year. In summary, high quality flow and EC data have been obtained at this site.

Comments

However, the location is not ideal because it is on a bend in the river. The stage-discharge relationship varies during high flows due to bank erosion and sediment deposit. The logistics for making current meter readings at this site are very difficult at high stages. Current meter measurements are taken from a boat.

Other Monitoring Stations

Stations G and H are located on the San Joaquin River. The CVRWQCB collected weekly grab samples at

Figure 7. Flow and Salinity in the San Joaquin River at Crows Landing (Station N)

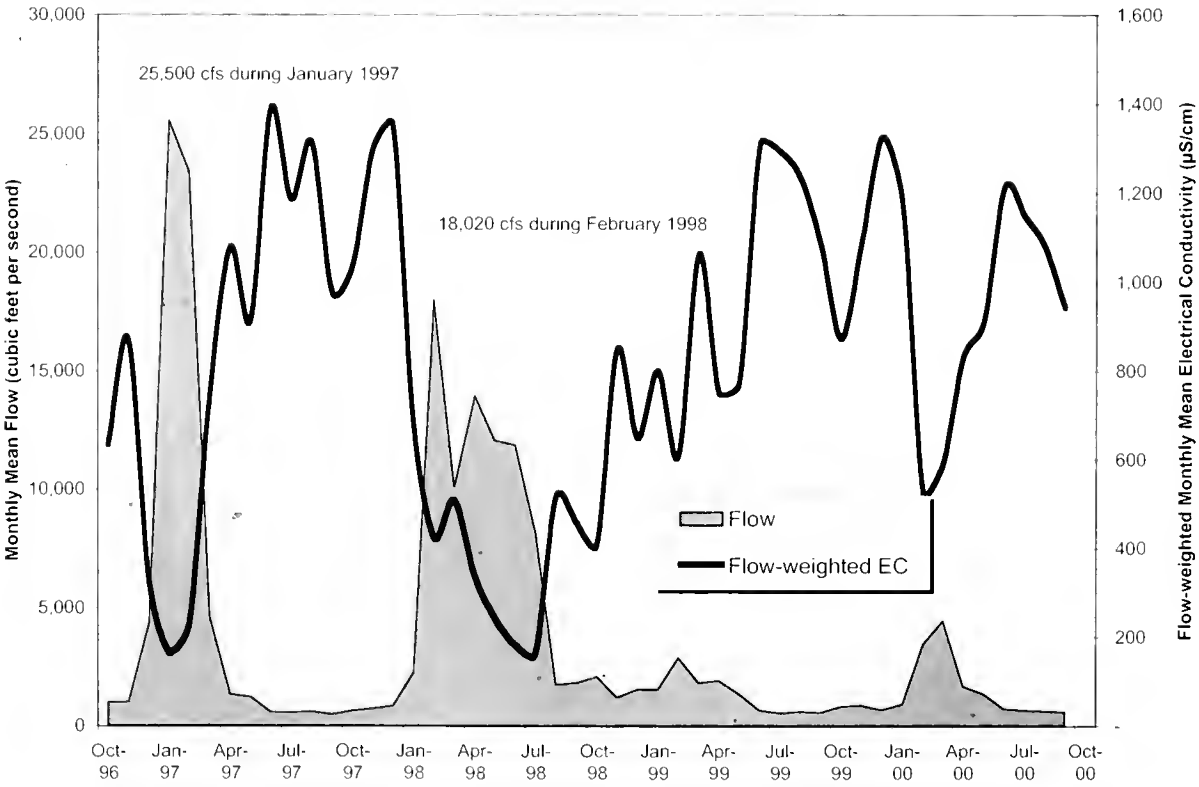


Table 7. Flow and Salinity in the San Joaquin River at Crows Landing (Station N), WY 1997–2000

	Flow				Salinity				
	Mean daily cfs		Total acre-feet		FW EC µS/cm		TDS mg/L	Salt load tons	
Oct-1996	1,013	G	62,290	G	633	Gr	392	33,262	Gr
Nov-1996	1,027	G	61,120	G	869	Gr	539	44,792	Gr
Dec-1996	4,364	G	268,300	G	326	Gr	202	73,753	Gr
Jan-1997	25,600	G	1,574,000	G	166	Gr	103	220,954	Gr
Feb-1997	23,390	G	1,299,000	G	231	Gr	143	253,517	Gr
Mar-1997	4,614	G	283,700	G	745	Gr	462	178,110	Gr
Apr-1997	1,353	G	80,480	G	1,078	Gr	668	73,128	Gr
May-1997	1,238	G	76,100	G	916	Gr	568	58,784	Gr
Jun-1997	605	G	35,980	G	1,390	Gr	862	42,186	Gr
Jul-1997	583	G	35,850	G	1,187	Gr	736	35,876	Gr
Aug-1997	612	G	37,630	G	1,315	Gr	815	41,729	Gr
Sep-1997	501	G	29,820	G	979	Gr	607	24,611	Gr
Oct-1997	648	G	39,860	G	1,037	Gr	643	34,861	Gr
Nov-1997	751	G	44,690	G	1,301	Gr	807	49,011	Gr
Dec-1997	866	G	53,260	G	1,352	Gr	838	60,705	Gr
Jan-1998	2,270	G	139,600	G	685	Gr	425	80,603	Gr
Feb-1998	18,020	G	1,001,000	G	427	Gr	265	360,319	Gr
Mar-1998	10,130	G	623,100	G	508	Gr	315	266,927	Gr
Apr-1998	13,980	G	832,100	G	339	Gr	210	238,007	Gr
May-1998	12,090	G	743,600	G	244	Gr	151	152,762	Gr
Jun-1998	11,890	G	707,300	G	183	Gr	113	109,320	Gr
Jul-1998	8,176	G	502,700	G	164	Gr	102	69,341	Gr
Aug-1998	1,757	G	108,100	G	518	Gr	321	47,242	Gr
Sep-1998	1,842	G	109,600	G	458	Gr	284	42,371	Gr
Oct-1998	2,092	G	128,600	G	410	Gr	254	44,509	Gr
Nov-1998	1,228	G	73,090	G	849	Gr	526	52,300	Gr
Dec-1998	1,553	G	95,490	G	650	Gr	403	52,295	Gr
Jan-1999	1,562	G	96,020	G	800	Gr	496	64,734	Gr
Feb-1999	2,909	G	161,500	G	609	Gr	378	82,991	Gr
Mar-1999	1,847	G	113,600	G	1,062	Gr	658	101,750	Gr
Apr-1999	1,937	G	115,200	G	751	Gr	466	72,955	Gr
May-1999	1,367	G	84,070	G	773	Gr	479	54,820	Gr
Jun-1999	684	G	40,690	G	1,310	Gr	812	44,925	Gr
Jul-1999	567	G	34,840	G	1,293	Gr	802	37,983	Gr
Aug-1999	615	G	37,810	G	1,233	Gr	764	39,320	Gr
Sep-1999	579	G	34,440	G	1,085	Gr	673	31,517	Gr
Oct-1999	836	G	51,890	G	874	Gr	542	38,233	Gr
Nov-1999	876	G	52,230	G	1,091	Gr	676	48,036	Gr
Dec-1999	695	G	42,230	G	1,327	Gr	823	47,265	Gr
Jan-2000	942	G	59,110	G	1,176	Gr	729	58,618	Gr
Feb-2000	3,480	G	201,700	G	530	Gr	329	90,098	Gr
Mar-2000	4,470	G	274,900	G	590	Gr	366	136,828	Gr
Apr-2000	1,690	G	100,200	G	833	Gr	516	70,370	Gr
May-2000	1,370	G	84,830	G	912	Gr	565	65,234	Gr
Jun-2000	739	G	43,800	G	1,214	Gr	753	44,821	Gr
Jul-2000	675	G	41,610	G	1,148	Gr	712	40,284	Gr
Aug-2000	630	G	38,800	G	1,080	Gr	670	35,341	Gr
Sep-2000	597	G	36,180	G	942	Gr	584	28,751	Gr

	average	totals	average	average	totals
WY 1997	5,408	3,844,270	820	508	1,080,703
WY 1998	6,868	4,904,910	601	373	1,511,470
WY 1999	1,412	1,015,350	902	559	680,098
WY 2000	1,417	1,027,480	976	605	703,876

References
G   U.S. Geological Survey published data
Gr   Flow-weighted average calculated from USGS 15 minute EC data

EC   Electrical conductivity
FW   Flow-weighted average concentration
TDS   Total dissolved solids

Table 8. Electrical Conductivity of Water Passing Other Monitoring Stations, WY 1997–2000

GBP Station	B	G	H	J	K	L	L2	M	M2
Site ID	11262895	MER538	STC512	MER505	MER506	MER532	MER563	MER519	MER545
Location	GBP Discharge San Luis Drain terminus	San Joaquin River at Fremont Ford	San Joaquin River at Hills Ferry	Camp 13	Agatha Canal	San Luis Canal	San Luis Canal, d/s of Splits	Santa Fe Canal	Santa Fe Canal, d/s of Splits
Sample Method	(d)	(wg)	(wg)	(wg)	(wg)	(wg)	(wg)	(wg)	(wg)
Units	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm
Oct-1996	3,948	972	1,268	371	394				
Nov-1996	3,830	1,185	1,345	449	445	934		595	
Dec-1996	4,095	581	773	325	623	715		738	
Jan-1997	4,142	104	274	201	268				
Feb-1997	4,872	101	245	886	2,217	1,383		1,098	
Mar-1997	4,669	825	1,219	1,755	185	1,165		1,285	
Apr-1997	5,380	1,838	2,508	1,520	540	1,400		1,475	
May-1997	4,730	1,766	2,260	779	511	839		839	
Jun-1997	4,642	1,233	1,800	951	466	845		1,052	
Jul-1997	4,206	1,167	1,712	672	415	751		864	
Aug-1997	3,497	1,000	1,495	757	384	749		815	
Sep-1997	3,077	1,383	1,653	445	411	568		576	
Oct-1997	4,425	1,220	1,506	531	501	648		810	
Nov-1997	4,206	1,583	1,715	760	661	760		1,165	
Dec-1997	4,398	1,793	1,858	2,638	818	1,858		1,892	
Jan-1998	4,919	1,563	1,630	2,728	1,450	1,363		2,738	
Feb-1998	3,397	229	821	2,115	2,948	1,998		2,080	
Mar-1998	4,788	340	843	3,055	1,285	2,078		2,200	
Apr-1998	5,258	145	602	2,435	2,631	1,643		1,668	
May-1998	5,494	95	438	686	415	1,292		843	
Jun-1998	4,576	75	269	1,167	113	826		454	
Jul-1998	4,020	156	396	190	114	802		483	
Aug-1998	3,983	633	1,138	375	380	858	594	637	1,222
Sep-1998	3,798	608	1,031	280	316	441	406	442	573
Oct-1998	4,738	673	887	267	275	670	415		783
Nov-1998	4,909	1,015	1,234	338	367	840	435		952
Dec-1998	4,881	606	933	257	256		277		1,338
Jan-1999	4,628	1,268	1,575	701	1,221		595		1,810
Feb-1999	4,467	915	1,223	637	883		867		1,908
Mar-1999	5,117	1,486	1,856	794	1,471		711		2,042
Apr-1999	5,512	1,546	1,778	779	664		800		1,823
May-1999	4,637	1,518	1,838	442	409		552		955
Jun-1999	4,471	1,458	2,163	526	439		1,574		1,084
Jul-1999	4,380	1,136	1,953	521	385		1,281		1,125
Aug-1999	3,960	1,022	1,680	551	320		844		1,215
Sep-1999	4,094	1,017	1,488	447	472		507		590
Oct-1999	4,482	1,225		536	509		552		829
Nov-1999	4,253	1,493		614	598		845		1,059
Dec-1999	4,383	2,022		1,011	859		817		1,832
Jan-2000	4,355	1,971		743	685		868		1,730
Feb-2000	4,622	1,161		992	1,111		1,721		2,358
Mar-2000	5,047	829		605	466		694		2,258
Apr-2000	4,863	1,416		661	556		749		1,548
May-2000	4,238	1,430		651	535		822		1,084
Jun-2000	4,190	1,218		596	480		1,179		984
Jul-2000	3,899	949		500	411		1,265		1,084
Aug-2000	3,485	998		675	397		1,148		1,043
Sep-2000	3,792	1,143		419	393		442		493

	average	average	average	average	average	average	average	average	average
Water Year 1997	4,257	1,013	1,379	759	572	935		934	
Water Year 1998	4,439	703	1,021	1,413	969	1,214	500	1,284	898
Water Year 1999	4,650	1,138	1,551	522	597	755	738		1,302
Water Year 2000	4,301	1,321		667	583		925		1,359

(d) Flow-weighted averages calculated from USGS 15 minute EC data
(wg) Monthly averages calculated from CVRWQCB lab data of weekly grab samples

Station G, and the EC of each sample was measured in a laboratory. The CVRWQCB did not collect water quality samples at Station H during WY 2000. Flow is not measured at these locations.

The CVRWQCB also collected weekly water quality samples at Stations J, K, L2, and M2 (Camp 13, Agatha, San Luis, and Santa Fe Canals, respectively). The purpose of these sites is to ensure that no agricultural drainage water from the GDA enters wetland supply channels in Grasslands Water District. The EC of each sample was measured in the laboratory. Flow is not measured at these locations.

Table 8 summarizes EC measurements of water that passed these stations during the four years of the Project. The data show an increase in salinity as water passes across the southern portion of Grassland Water District. During WY 2000, the average salinity of water in wetland water supply channels, measured at Station G (Fremont Ford), was 1,321 µS/cm.

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Introduction

The monitoring program for the Grassland Bypass Project (GBP), including water quality monitoring, is described in detail in Compliance Monitoring Program for the Use and Operation of the Grassland Bypass Project (USBR et al., 1996). This chapter provides a summary of the water quality monitoring program, modifications to the plan for the fourth year of operation of the GBP (October 1, 1999 to September 30, 2000), and water quality trends observed during four years of operation of the GBP. Detailed data of water quality results of individual monitoring stations will not be provided in this summary, as the San Francisco Estuary Institute (SFEI) has presented this information in another report (SFEI, 2001).

Monitoring Program

The Central Valley Regional Water Quality Control Board (CVRWQCB) has an on-going water quality monitoring program related to regulatory activities for agricultural subsurface drainage from the Grassland watershed. The water quality monitoring program for the GBP is an adaptation of the CVRWQCB monitoring program. The CVRWQCB is responsible for most of the water quality sampling with assistance from the Panoche Water District (under contract with the San Luis & Delta-Mendota Water Authority; SLDMWA). The Panoche Water District collects samples at Stations A, J, K, L2, and M2. Samples are transferred to and processed by the CVRWQCB and analyzed by its contract laboratories. The CVRWQCB conducts quality assurance (QA) reviews of the data before submitting them to the SFEI for reporting. However, all CVRWQCB data are provisional and subject to change until the CVRWQCB approves its annual agency report on the water year (WY) 2000 monitoring results.

Monitoring Objectives

The water quality monitoring program was designed to provide data for evaluating compliance with commitments in the project Waste Discharge Requirements, the Use Agreement, and associated documents. The commitments include:

- Monthly and annual selenium load limits on discharges
- No degradation of the San Joaquin River water quality relative to the pre-project-condition
- Cessation of discharge of agricultural subsurface drainage to the wetland channels
- Management of flows in the San Luis Drain (SLD) so as to not mobilize channel sediments

The Monitoring Program was also designed to verify the validity of assumptions expressed in documents associated with the GBP. The assumptions include:

- The GBP is expected to result in selenium concentrations less than 2 µg/L in approximately 93 miles of wetland water supply channels.
- It is believed that the increased frequency of exceeding selenium water quality objectives in Mud Slough (north) will be offset by a reduction of exceedances in Salt Slough.

In addition, the Monitoring Program was intended to provide data to be used to assess spatial and temporal trends in water quality parameters of concern and to characterize habitats in which biological samples were collected.

Sampling Locations

Monitoring was to be conducted in four areas; the SLD, Mud Slough (north), the San Joaquin River, and the Grassland wetland water supply channels, including Salt Slough. Table 1 summarizes the Monitoring Program, and sampling locations are depicted in Figure 2 in Chapter 1.

Frequency of Sampling

The frequency of sampling is outlined in Table 1. Weekly composite samples were collected at Station A (inflow to the SLD). Daily composite samples were collected at Station B (discharge form the SLD), and at Station N (San Joaquin River at Crows Landing). At Station A, daily samples were composited into a weekly sample to be used along with continuous flow data to calculate weekly selenium load inflow to the SLD. At Station B, daily composite samples along with continuous flow data were used to calculate daily selenium load discharge to Mud Slough (north). At Station N, daily composite samples were collected to allow the CVRWQCB to calculate loads and evaluate progress toward compliance with Basin Plan water quality objectives (CVRWQCB, 2001). The compliance date at Station N for the selenium water quality objective (5 µg/L 4-day average)

Table 1. Summary of Water Quality Monitoring Plan

Location	Site	Description	Purpose	Analytical Parameter	Frequency	Sampling Methodology
San Luis Drain	A	inflow to SLD	water quality of inflow (Se and TSS)	Se B EC EC, TSS	weekly composite weekly	auto-sampler mid-channel, depth integrated
	B	discharge from SLD	water quality of discharge (Se and TSS) (for Se load calculation)	Se, B EC Se, B, EC TSS	daily composite weekly	auto-sampler mid-channel depth integrated
Mud Slough (north)	C	upstream of SLD discharge	Mud Slough (north) base water quality prior to receiving drainage discharges	Se, B, EC	weekly	grab
	D	downstream of discharge	Mud Slough (north) water quality as impacted by drainage discharge	Se B EC	weekly	mid-channel, depth integrated
	I	back water	water quality impact of Mud Slough (north) flooding in Kesterson Refuge	Se B EC	annually	N/A
Wetland Channels	F	Salt Slough	water quality of habitat and to track improvements in former drainage conveyance channel	Se, B EC	weekly	grab
	J	Camp 13	verify no discharge of drainage provision	Se B EC	weekly	grab
	K	Agatha Canal	verify no discharge of drainage provision	Se, B, EC	weekly	grab
	L2	San Luis Canal	water quality of wetland water supply channel	Se, B, EC	weekly	grab
	M2	Santa Fe Canal	water quality of wetland water supply channel	Se B, EC	weekly	grab
San Joaquin River	G	at Fremont Ford (upstream of drainage inflow)	track improvements in former drainage conveyance channel and characterize water quality of habitat	Se, B EC	weekly	grab
	H	at Hill's Ferry (downstream of drainage inflow)	intended to represent water quality of river most impacted by drainage discharge	Se B, EC	discontinued, determined to be downstream of seasonal Merced River inflows	grab
	N	at Crows Landing (downstream of Merced River confluence)	characterize water quality of habitat	Se B, EC Se, B, EC	daily composite weekly	auto-sampler grab

during normal and wet years is October 1, 2005, and during critical years is October 1, 2010. Since the objective is based on a 4-day average concentration, consecutive daily samples are required at this station. The remaining stations were sampled on a weekly basis.

Sampling Methodology

Three types of sampling techniques were utilized depending on the frequency of sampling and data needs: auto-sampler, mid-channel depth-integrated, and grab sample from channel bank. Auto-samplers were used to collect daily and weekly composite samples because of the remoteness of the project station and frequency of sampling. At Stations A, B, and D, structures such as a bridge or platform over the channel permitted the collection of mid-channel, depth-integrated samples. At other stations, a grab sample was collected from the stream bank. With respect to stream hydrology, lateral and vertical homogeneity was assumed for dissolved constituents at all sampling stations.

Modifications to the Water Quality Monitoring Program

During the previous three years of the GBP a number of issues were resolved with respect to the water quality monitoring program. These modifications and clarifications to the monitoring program are discussed in the first Annual Report (USBR, 1998), the second Annual Report (SFEI, 1999), and the third Annual Report (SFEI, 2000).

During the fourth year of the GBP it was decided that water quality monitoring at Station H would be conducted by the SLDMWA. The results of the monitoring would be used in conjunction with the biological monitoring portion of the GBP. As the data were collected separate from the water quality monitoring program, the data are not included in this chapter. The data are presented in Chapter One of this report.

Water Quality Trends

Detailed water quality data for each monitoring station are presented in the Grassland Bypass Project Annual Narrative and Graphical Summary, October 1999 to September 2000 (SFEI, 2001). Thus, this presentation will be limited to major water quality trends and findings for the four years of operation of the GBP. Of primary interest are selenium concentrations in the San Joaquin River and water quality trends in Mud Slough (north). Also of interest are exceedances in the wetland channels of selenium water quality objectives established in the Water Quality Control Plan for the Sacramento/San Joaquin River Basins (Basin Plan; CVRWQCB, 1996).

Figure 1. Selenium Concentration in the San Joaquin River, Water Years 1997, 1998, 1999, and 2000

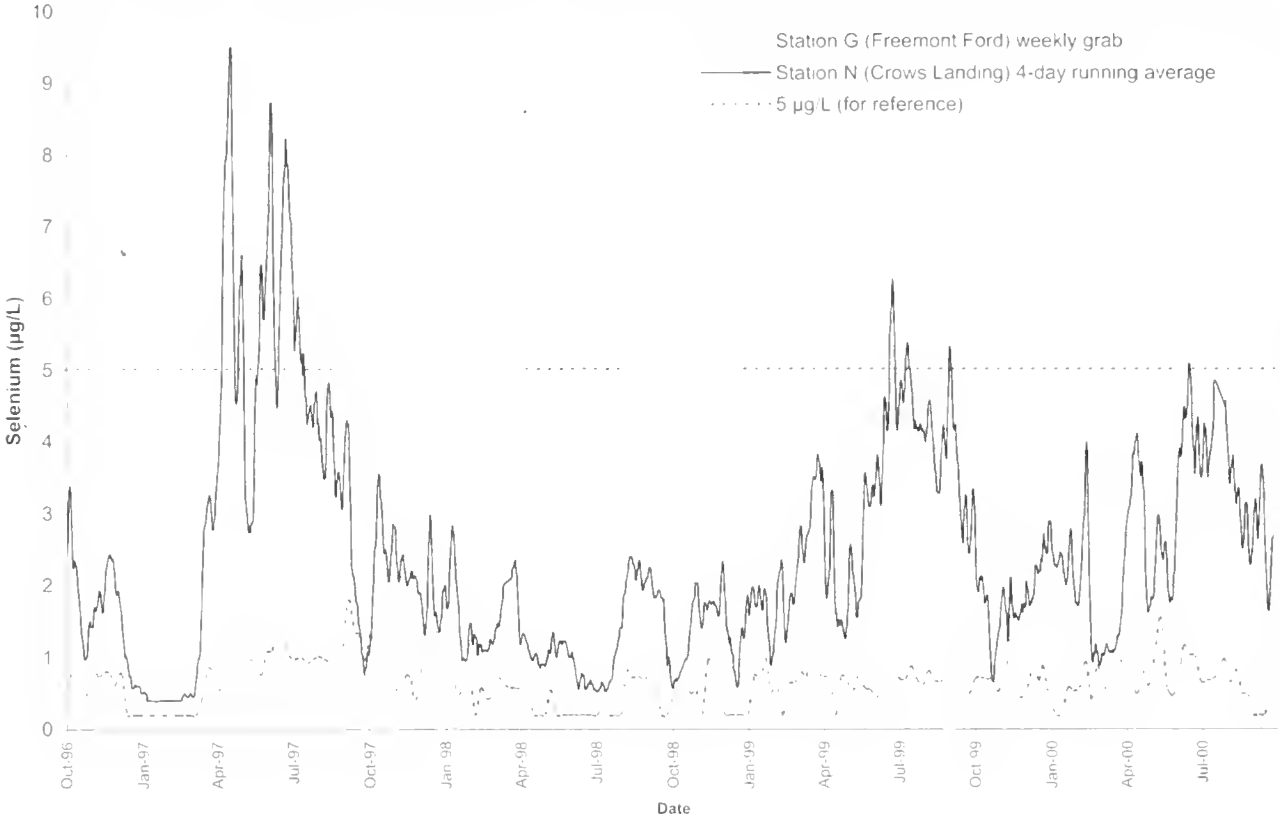


Figure 2. Mean Monthly Selenium Concentration in the Wetland Channels
October 1, 1999 to September 30, 2000

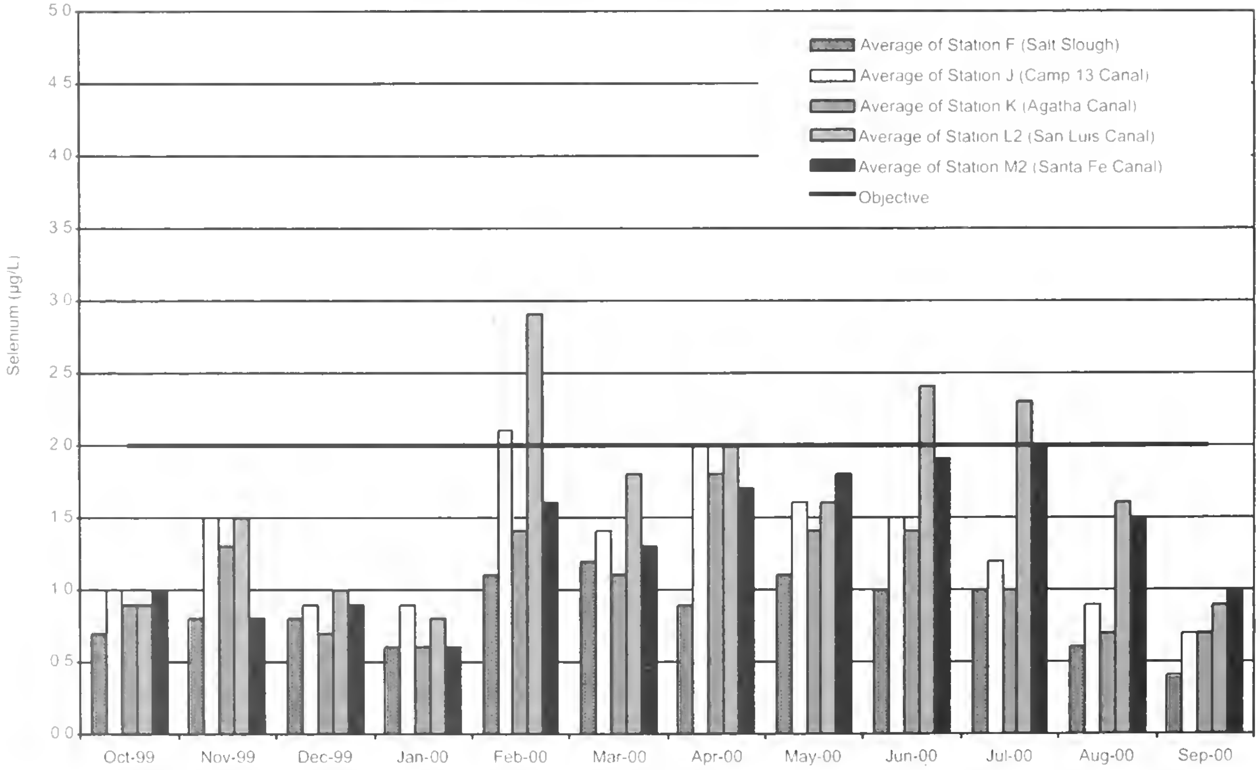


Table 2. Summary of Selenium Water Quality Objectives and Compliance Time Schedule [Selenium Water Quality Objectives (in bold) and Performance Goals (in italics)]

Water Body/Water Year Type [1]	1 October, 1996	1 October, 2002	1 October, 2005	1 October, 2010
San Joaquin River below the Merced River; Above Normal, and Wet Water Year Types		*5 µg/L monthly mean*	***5 µg/L 4-day average***	
San Joaquin River below the Merced River; Critical, Dry, and Below Normal Water Year Types		*8 µg/L monthly mean*	*5 µg/L monthly mean*	***5 µg/L 4-day average***
San Joaquin River from Sack Dam to the Merced River				***5 µg/L 4-day average***

[1] The water year classification will be established using the best available estimate of the 60-20-20 San Joaquin Valley water year hydrologic classification (as defined in Footnote17 for Table 3 in the State Water Resources Control Board's *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary*, May 1995) at the 75% exceedance level using data from the Department of Water Resources Bulletin 120 series. The previous water year's classification will apply until an estimate is made of the current water year.

San Joaquin River

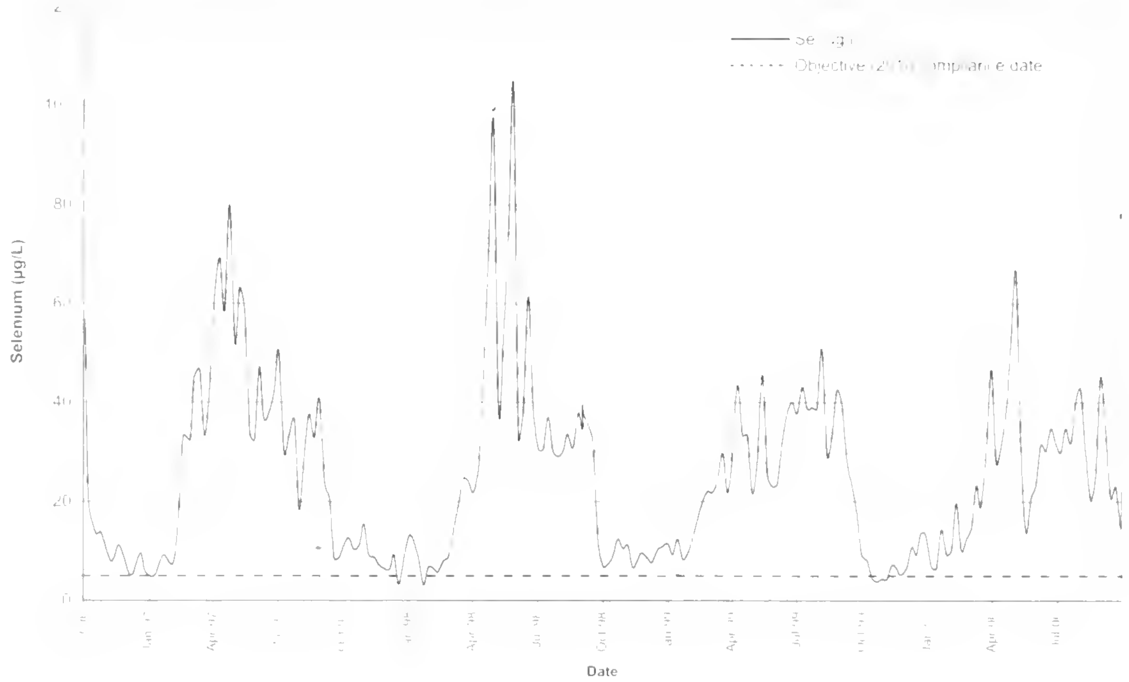
Figure 1 depicts selenium concentrations in the San Joaquin River at monitoring Stations G (weekly grab), and N (4-day moving average) for WY's 1997, 1998, 1999, and 2000. Station G is located at Fremont Ford, upstream of the Mud Slough (north) inflow to the San Joaquin River. Because this station is located upstream of GBP service area drainage discharges (except during flood events when drainage has been routed to Salt Slough), selenium concentrations are usually relatively low. Station N is located downstream of the GBP and the Merced River inflow to the San Joaquin River. Merced River inflows contain low concentrations of selenium that dilute the upstream selenium contributions (CVRWQCB, 2001). Selenium concentrations at Station N were elevated with respect to the background levels at Station G.

The Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) contains a schedule for compliance with the 5 µg/L (4-day average) selenium water quality objective. The compliance date is either October 1, 2005 or October 1, 2010, depending on location and type of water year (wet, dry, etc.) (Table 2). The water quality objective is depicted in Figure 1 for comparison purposes. Selenium concentrations frequently exceeded a 5 µg/L (4-day average) during WY 1997 at Station N. In contrast, selenium concentrations remained below a 5 µg/L (4-day average) during WY 1998 for both of the San Joaquin River monitoring stations. During WY 1999, selenium exceeded a 5 µg/L (4-day average) during the months of June, July, and August, at Station N. During WY 2000, selenium concentrations remained below a 5 µg/L (4-day average) for all months at Station G. During the month of June, a 5 µg/L (4-day average) was exceeded at Station N.

Wetland Channels

Monthly mean selenium concentrations in the wetland channels for WY 2000 are depicted in Figure 2. The monthly mean 2 µg/L selenium objective was exceeded in February at Station J (Camp 13 Canal) and L2 (San Luis Canal). Monthly mean flow at Station J was low (2 cfs). Monthly mean flow at Station L2 was also low (11 cfs). The monthly mean 2 µg/L selenium objective was exceeded in June and July at Station L2. Monthly mean flow at Station L2 was also relatively low during June and July (12.5 cfs and 10 cfs, respectively). Note that the maximum monthly mean selenium concentration for all stations was 2.9 µg/L. The monthly mean 2 µg/L

Figure 3. Weekly Grab Selenium Concentration at Station D (Mud Slough (north) Downstream of SLD) for WYs 1997, 1998, 1999, and 2000



selenium objective was met throughout WY 2000 at Station F (Salt Slough), Station K (Agatha Canal), and Station M2 (Santa Fe Canal).

The CVRWQCB conducted a preliminary investigation to identify sources of selenium and initiate actions to achieve compliance with the water quality objectives for the wetland channels (CVRWQCB, 2000). In addition to commingled drainage and storm runoff during major storm events, other potential sources of selenium identified in wetland channels include: supply water, agricultural subsurface drainage from outside of the GBP area, and groundwater seepage. The GAF have initiated a number of corrective activities since WY 1998, including: reducing commingling of subsurface drainage with stormwater, and redirecting subsurface drainage from outside of the GBP service area. The CVRWQCB is continuing its investigations to isolate selenium sources to the channels in February and the mid-irrigation season.

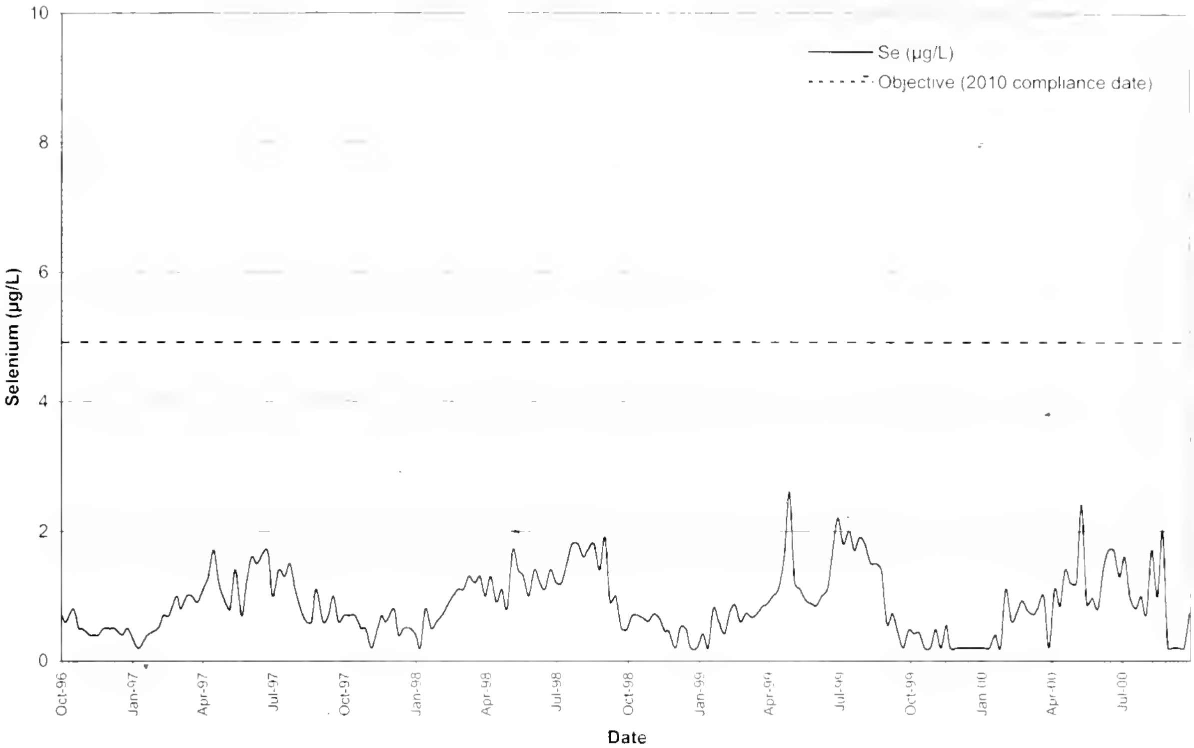
Mud Slough (North)

Results of weekly grab sampling for selenium at Station D, Mud Slough (north) downstream of the SLD, are depicted in Figure 3. Selenium concentration distributions as a function of time were similar for all WY's. Selenium concentrations tend to be lowest from the fall through early winter (non irrigation period) and highest during the irrigation period, which commences in mid winter (pre-plant irrigation) and lasts through the summer. During Water Year 2000, selenium concentrations in Mud Slough (north) downstream of the SLD ranged from 3.7 µg/L in October, to 66 µg/L in May. Water quality in Mud Slough (north) downstream of the SLD is dominated by the GBP drainage discharge. For comparison purposes, the 5 µg/L (4-day average) selenium water quality objective, which applies October 1, 2010 for Mud Slough (north), is noted on Figure 3. Selenium concentrations regularly exceeded 5 µg/L in Mud Slough (north) downstream of the SLD inflow. Upstream of the drainage discharge, the concentration of selenium was usually below 2 µg/L (Figure 4).

Boron Water Quality Objectives

Mean monthly boron objectives and WY 2000 boron concentrations for Mud Slough, Salt Slough, and the San Joaquin River are depicted in Table 3. Exceedances of the 2.0 mg/L objective occurred at Station D from March through September. The 0.8 mg/L objective was exceeded at Station N from June through August. Sources of boron extend throughout the San Joaquin Basin and are not restricted to the GBP. The CVRWQCB is conducting a separate, although concurrent, effort to control salt and boron loading to the lower San Joaquin Basin.

Figure 4. Weekly Grab Selenium Concentration at Station C (Mud Slough (north) Upstream of SLD) for WYs 1997, 1998, 1999, and 2000



Conclusions

Four years of GBP monitoring have shown that selenium concentrations in the San Joaquin River are a function of location in the River with respect to discharge points and tributary inflows, and of the assimilative capacity of the River. The lowest selenium concentrations in the San Joaquin River are upstream of Mud Slough (north) inflows. Mud Slough (north) inflow contains relatively high concentrations of selenium. The Merced River water dilutes the San Joaquin River water with respect to selenium; however, selenium concentrations in the San Joaquin River at Crow's Landing remain elevated relative to the background condition in the San Joaquin River at Freemont Ford.

The selenium water quality objective (2 µg/L monthly mean) was exceeded in two of the wetland supply channels during water year 2000, although the maximum monthly mean recorded was 2.9 µg/L at Station L2 in February. A number of sources may contribute to the violation of selenium water quality objectives in the wetland channels, including agricultural subsurface drainage external to the GBP being discharged to the channels upstream of the wetlands. The CVRWQCB is evaluating control actions to reduce selenium concentrations in the wetland channels.

The water quality of Mud Slough (north) downstream of the SLD inflow is governed by the drainage discharge and fluctuates widely. Selenium concentrations tend to be lowest from the fall through early winter

Table 3. Boron Water Quality Objective Exceedances in the Grassland Watershed and San Joaquin River: Water Year 2000.

Station ID	Description	Mean Monthly Concentration (mg/L)												Monthly WQO
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
C	Mud Slu (N) upstrm of SLD Discharge	a	a	a	a	a	1.8	1.9	1.5	1.6	1.6	1.5	0.51	2.0
D	Mud Slu (N) dwnstrm of SLD Discharge	a	a	a	a	a	3.7	5.0	4.9	5.9	6.0	5.8	3.9	2.0
F	Salt Slough at Lander Avenue	a	a	a	a	a	1.1	0.70	0.69	0.56	0.50	0.51	0.56	2.0
G	SJR at Fremont Ford	a	a	a	a	a	0.50	0.56	0.55	0.49	0.48	0.45	0.46	2.0
N	SJR at Crows Landing Weekly Grab Samples	0.70	0.70	0.90	0.90	0.70	0.50	0.70	0.60	1	1	0.90	0.60	1.0/0.8
N	SJR at Crows Landing Daily Autosamples	0.65	0.73	0.87	0.88	0.71	0.47	0.71	0.60	0.99	0.95	0.93	0.65	1.0/0.8

= water quality objective exceedance
WQO = water quality objective in mg/L
NA = not applicable, no boron objective applies

a objective only applies 15 March through 15 September
1.0 mg/L applies 16 September through 14 March
0.8 mg/L applies 15 March through 15 September

(non-irrigation period) and highest during the irrigation period, which commences in mid winter (pre-plant irrigation) and lasts through the summer. Selenium regularly exceeded 5 µg/L in Mud Slough (north) downstream of the SLD inflow, and reached a maximum of 66 µg/L in May 2000. Upstream of the drainage discharge, the concentration of selenium was usually below 2 µg/L.

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Flow, Salt and Selenium Mass Balances in the San Luis Drain

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GRASSLAND BYPASS PROJECT

Summary

Although lined with concrete along the 28 mile reach utilized by the Grassland Bypass Project (GBP), a total of about 1,900 acre-feet of water entered the San Luis Drain (SLD) between Stations A and B during October 1999 through January 2000, and in September 2000. There was a net increase in salt load of about 5,600 tons during WY 2000. There was a net decrease of about 65 pounds of selenium (about 1%) between the monitoring sites during WY 2000.

The reasons for these differences may be due to water seeping into the SLD when adjacent wetlands are flooded, or possibly analytical errors. Tables 1, 2, 3, and 4 summarize monthly flows and loads of salt and selenium in water that passed Stations A and B during the four years of the Project.

Note that historical concentration and load values have been updated and differ from those in the WY 1999 annual report and errata sheets.

Background

Seepage into the SLD most likely occurs through one-way weep valves that equalize hydraulic pressure to prevent the concrete lining from buckling. Along the SLD, the water surface elevation of adjacent wetlands, when flooded in the fall and winter, is often higher than the elevation of water in the SLD.

Leakage from the SLD can occur where the concrete lining is fractured or between adjacent concrete panels. Other losses from the SLD include direct evaporation of water and evapotranspiration by algae and aquatic plants. Seepage into the SLD most likely occurs at rates many times greater than seepage out of the SLD, although measurements have not been made.

Flow Differences between Stations A and B

Table 1 summarizes the amount of water that flowed past Stations A and B during the four years of the Project. Figure 1a compares the flow of water that passed Stations A and B each month during WY 2000. Figure 1b compares the monthly flow of water that passed Stations A and B for all four years of the GBP.

Up to 37% more water flowed past Station B than Station A during WY 2000. This occurred between October 1999 and April 2000, and again in September 2000 while adjacent wetlands were flooded. Similar increases have occurred in the autumn and winter of previous years.

Figure 1a. Comparison of Flows in the San Luis Drain (WY 2000)

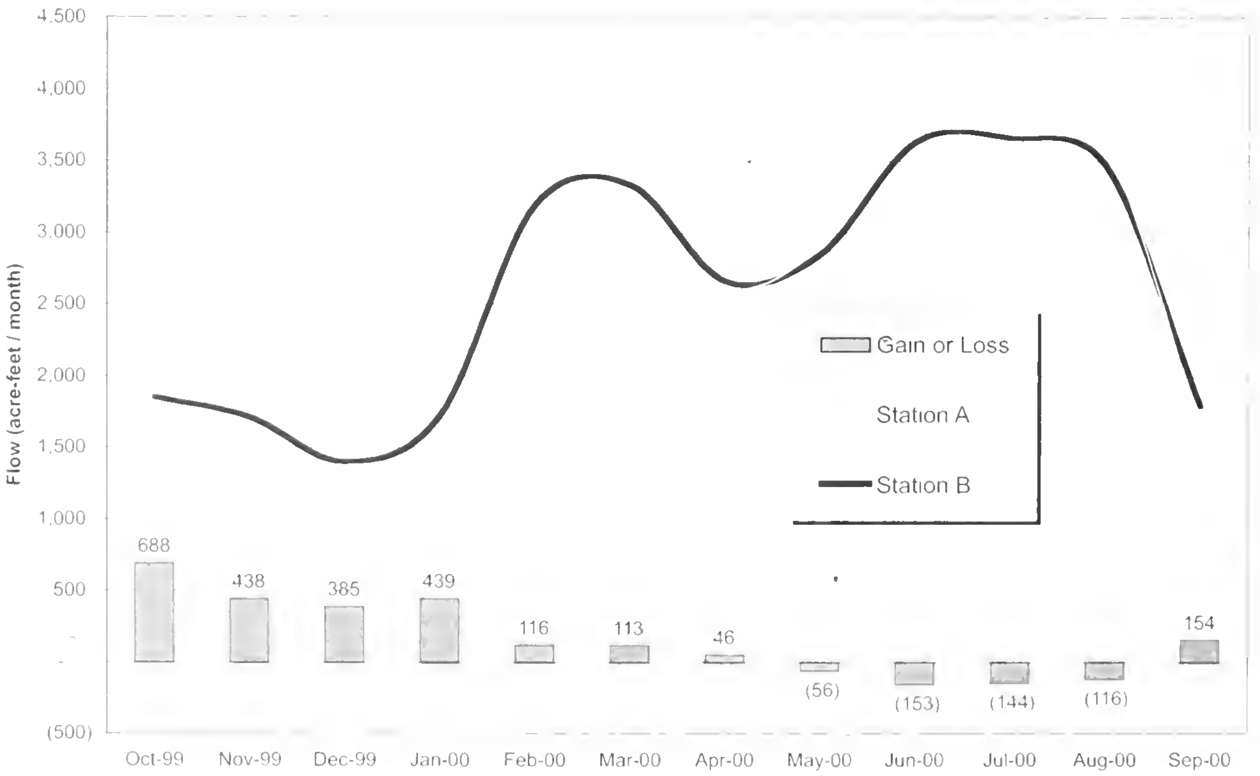


Table 1. Comparison of Flow Measurements

	Average Flow							
	Station A cfs		Station B cfs		Station A af/month	Station B af/month	Difference	Percent of Station B
Oct-1996	22.0	Lr	20.8	Lr	1,350	1,276	(74)	-6%
Nov-1996	24.2	Lr	26.4	Lr	1,437	1,569	132	8%
Dec-1996	29.6	Lr	31.7	Lr	1,818	1,946	128	7%
Jan-1997	62.2	Lr	60.2	Lr	3,827	3,703	(124)	-3%
Feb-1997	78.4	Lr	75.1	Lr	4,356	4,173	(183)	-4%
Mar-1997	83.5	Lr	79.3	Lr	5,131	4,876	(255)	-5%
Apr-1997	77.6	Lr	74.8	Lr	4,619	4,453	(166)	-4%
May-1997	69.9	Lr	68.6	Lr	4,301	4,215	(86)	-2%
Jun-1997	54.6	Lr	58.1	Lr	3,251	3,457	206	6%
Jul-1997	53.0	Lr	53.3	Lr	3,257	3,277	20	1%
Aug-1997	49.7	Lr	51.4	Lr	3,055	3,159	104	3%
Sep-1997	23.3	Lr	24.3	Lr	1,384	1,445	61	4%
Oct-1997	21.7	Lr	28.6	Lr	1,335	1,756	421	24%
Nov-1997	16.7	Lr	26.2	Lr	994	1,558	564	36%
Dec-1997	17.4	Lr	22.9	Lr	1,070	1,406	336	24%
Jan-1998	20.0	Lr	23.1	Lr	1,230	1,421	191	13%
Feb-1998	123.0	Lr	125.9	Lr	6,833	6,993	160	2%
Mar-1998	115.1	Lr	115.6	Lr	7,075	7,106	31	0%
Apr-1998	91.5	Lr	92.9	Lr	5,444	5,527	83	2%
May-1998	76.7	Lr	79.5	Lr	4,714	4,890	176	4%
Jun-1998	61.0	Lr	61.1	Lr	3,629	3,635	6	0%
Jul-1998	73.8	Lr	74.3	Lr	4,538	4,572	34	1%
Aug-1998	62.6	Lr	63.1	Lr	3,849	3,883	34	1%
Sep-1998	47.7	Lr	53.7	Lr	2,839	3,193	354	11%
Oct-1998	27.6	G	33.2	G	1,700	2,040	340	17%
Nov-1998	20.4	G	25.7	G	1,210	1,530	320	21%
Dec-1998	18.6	G	23.6	G	1,140	1,450	310	21%
Jan-1999	22.7	G	27.6	G	1,390	1,700	310	18%
Feb-1999	54.8	G	59.6	G	3,040	3,310	270	8%
Mar-1999	52.3	G	56.0	G	3,220	3,450	230	7%
Apr-1999	35.9	G	34.9	G	2,140	2,080	(60)	-3%
May-1999	48.7	G	48.2	G	3,000	2,960	(40)	-1%
Jun-1999	60.9	G	60.7	G	3,620	3,610	(10)	0%
Jul-1999	64.8	G	63.0	G	3,990	3,870	(120)	-3%
Aug-1999	64.1	G	63.6	G	3,940	3,910	(30)	-1%
Sep-1999	34.9	G	40.3	G	2,080	2,400	320	13%
Oct-1999	18.9	S	30.0	G	1,162	1,850	688	37%
Nov-1999	21.4	S	28.8	G	1,273	1,710	438	26%
Dec-1999	16.5	S	22.8	G	1,015	1,400	385	28%
Jan-2000	20.8	S	27.9	G	1,281	1,720	439	26%
Feb-2000	53.4	S	55.5	G	3,074	3,190	116	4%
Mar-2000	52.3	S	54.2	G	3,217	3,330	113	3%
Apr-2000	43.9	S	44.8	G	2,614	2,660	46	2%
May-2000	47.3	S	46.4	G	2,906	2,850	(56)	-2%
Jun-2000	63.6	S	61.0	G	3,783	3,630	(153)	-4%
Jul-2000	61.9	S	59.5	G	3,804	3,660	(144)	-4%
Aug-2000	58.3	S	56.5	G	3,586	3,470	(116)	-3%
Sep-2000	27.5	S	30.1	G	1,637	1,790	154	9%

	Average	Average	Totals	Totals		
WY 1997	52.3	52.0	37,786	37,550	(237)	-1%
WY 1998	60.6	63.9	43,550	45,939	2,389	5%
WY 1999	42.1	44.7	30,470	32,310	1,840	6%
WY 2000	40.5	43.1	29,350	31,260	1,910	7%

Data Source
- G US Geological Survey
- Lr Calculated from Lawrence Berkeley Laboratory data
- S San Luis & Delta-Mendota Water Authority

Summers Engineering analyzed this situation. Table 4 calculates the net discharge in acre-feet per month by taking into account precipitation and evaporation from the surface area of the SLD. Once precipitation and evaporation are accounted for, the differences in flow between Stations A and B range from −2% to +5% for February through August 2000. These differences are within the margin of error for flow measurements specified in the Quality Assurance Project Plan. The remaining months (October 1999 – January 2000, September 2000) show significant gains of water. This is most likely seepage into the SLD from adjacent wetland ponds.

Salt Mass Balance between Stations A and B

Table 2 compares monthly loads of salts in water that passed Stations A and B during the four years of the Project. About 5,600 tons of salt entered the SLD during this water year.

Figure 2a shows the monthly loads of salt in water that passed Stations A and B during the WY 2000. More salt flowed past Station B than Station A, particularly during the autumn and winter months. Figure 2b shows the monthly loads of salt in water that passed both sites during the four years of the Project.

Since salinity is a conservative chemical constituent, the monthly salt load measured at Station A should be identical to that at Station B. An increase in salt load must infer inflow of saline water into the SLD from adjacent wetlands if other factors such as precipitation and evaporation are taken into account. Drift in the EC sensor response can also affect the computation of salt load. However, EC is measured with identical sensors and methods at both sites.

Selenium Mass Balance between Stations A and B

A simple mass balance of selenium was calculated to better understand the dynamics of selenium mass transport and mass transfer within the San Luis Drain. Selenium is a non-conservative chemical constituent. These data are presented in Table 3. Despite the seepage inflow, there is little difference in the loads of selenium that passed each station. About 65 pounds of selenium that entered the SLD at Station A did not flow past Station B.

Figure 1b. Comparison of Flows in the San Luis Drain (WY 1997–2000)

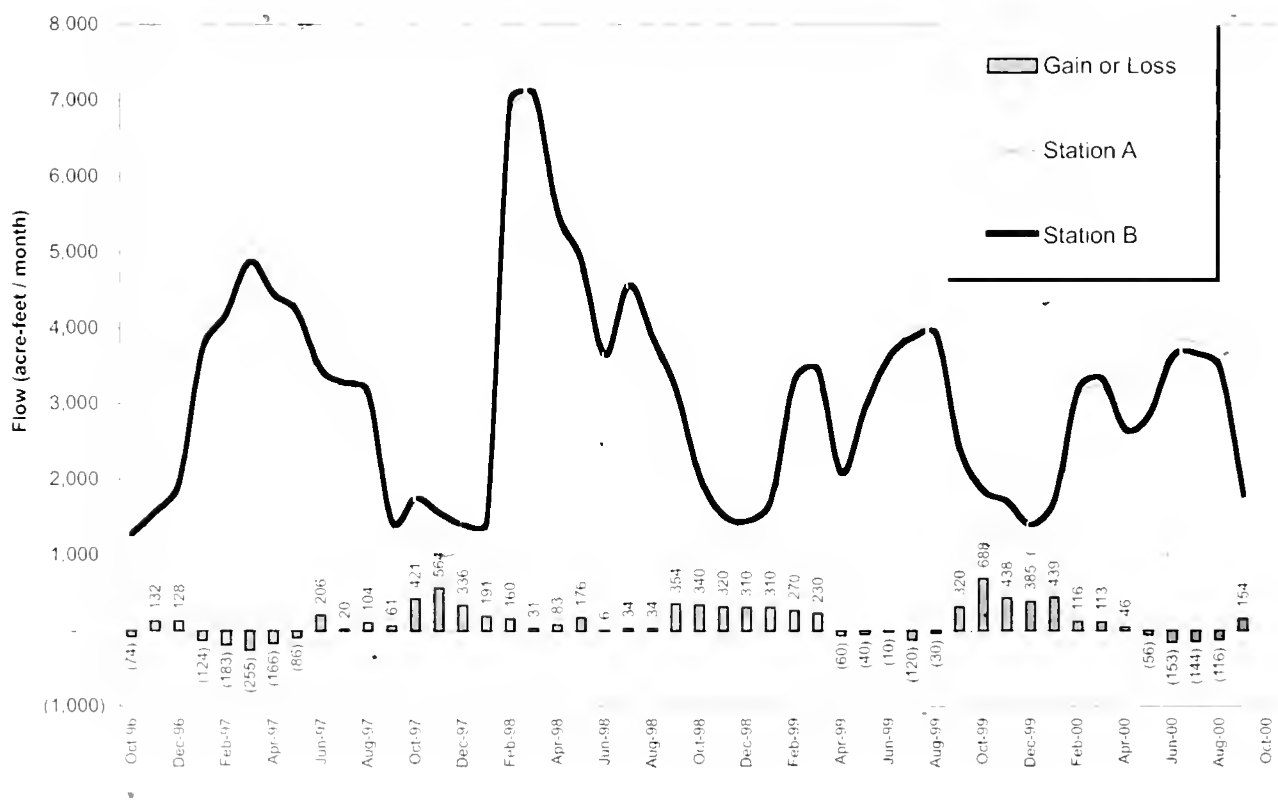


Figure 2a. Comparison of Salt Loads in the San Luis Drain (WY 2000)

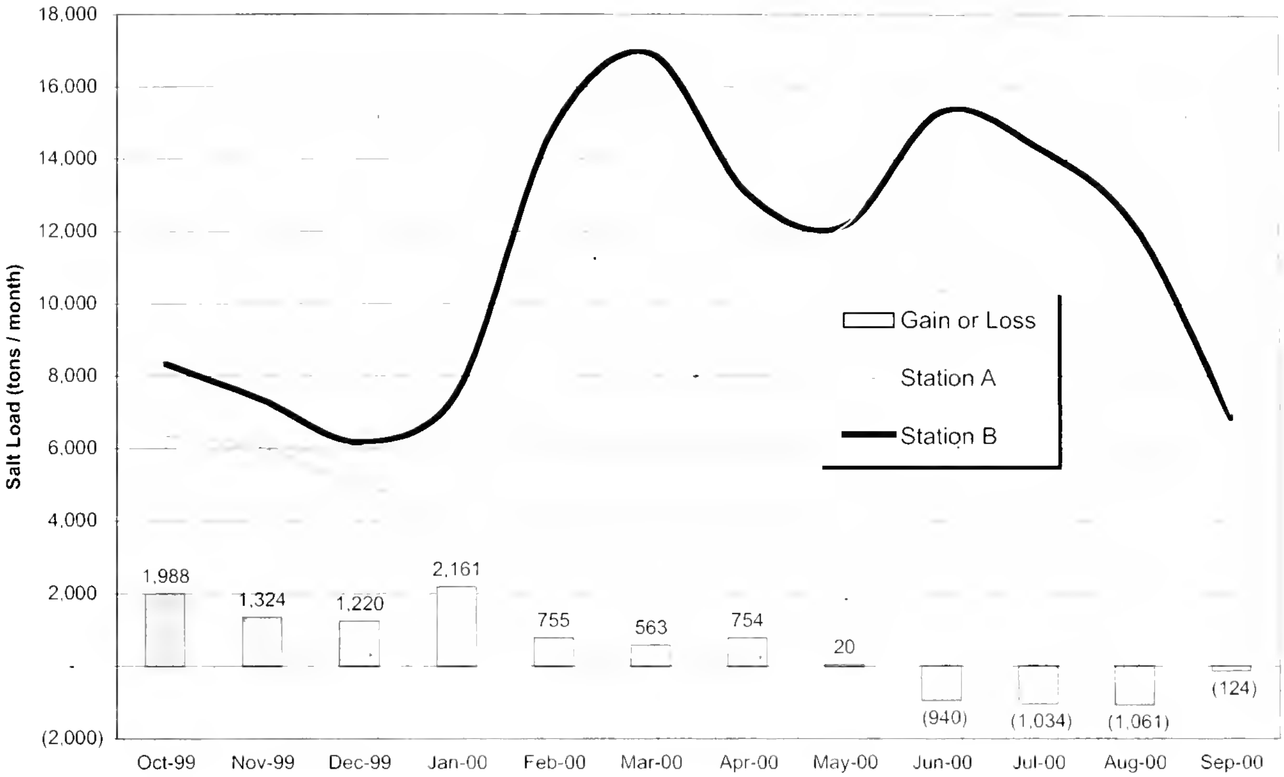


Figure 2b. Comparison of Salt Loads in the San Luis Drain (WY 1997–2000)

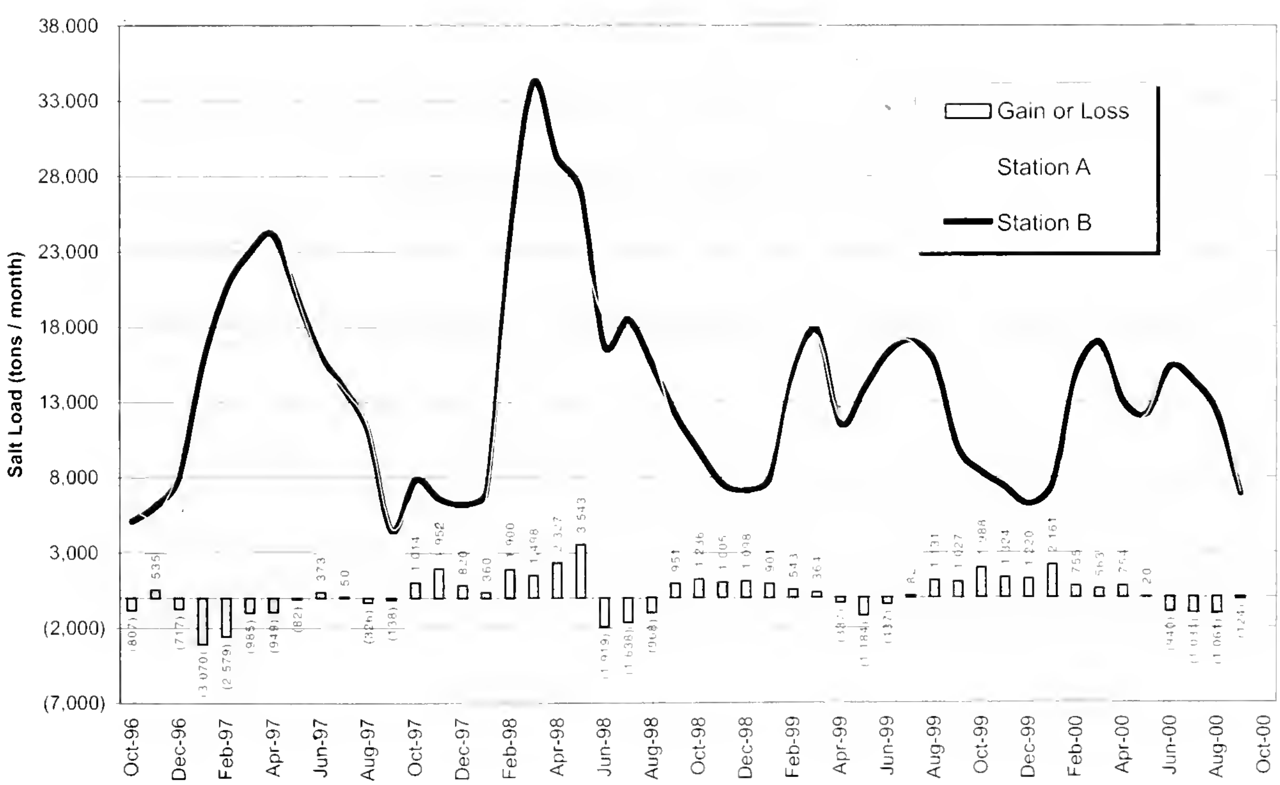


Table 2. Comparison of Salinity and Salt Loads

	Flow-weighted Electrical Conductivity				Loads			
	Station A µS/cm		Station B µS/cm		Station A tons/month	Station B tons/month	Difference	Percent of Station B
Oct-1996	4,326	Rt	3,948	L	5,877	5,070	(807)	-16%
Nov-1996	3,812	Rt	3,830	L	5,513	6,048	535	9%
Dec-1996	4,775	Rt	4,095	L	8,737	8,020	(717)	-9%
Jan-1997	4,804	Rt	4,142	L	18,503	15,433	(3,070)	-20%
Feb-1997	5,256	Rt	4,872	L	23,042	20,463	(2,579)	-13%
Mar-1997	4,628	Rt	4,669	L	23,898	22,913	(985)	-4%
Apr-1997	5,391	Rt	5,380	L	25,060	24,111	(949)	-4%
May-1997	4,654	Rt	4,730	L	20,145	20,063	(82)	0%
Jun-1997	4,823	Rt	4,642	L	15,780	16,153	373	2%
Jul-1997	4,217	Rt	4,206	L	13,823	13,873	50	0%
Aug-1997	3,722	Rt	3,497	L	11,443	11,117	(326)	-3%
Sep-1997	3,311	Rt	3,077	L	4,612	4,474	(138)	-3%
Oct-1997	5,065	Rt	4,425	L	6,805	7,819	1,014	13%
Nov-1997	4,640	Rt	4,206	L	4,642	6,594	1,952	30%
Dec-1997	5,016	Rt	4,398	L	5,401	6,221	820	13%
Jan-1998	5,393	Rt	4,919	L	6,676	7,036	360	5%
Feb-1998	3,200	Rt	3,397	L	22,006	23,906	1,900	8%
Mar-1998	4,599	Rt	4,788	L	32,746	34,244	1,498	4%
Apr-1998	4,914	Rt	5,258	L	26,923	29,250	2,327	8%
May-1998	4,952	Rt	5,494	L	23,493	27,036	3,543	13%
Jun-1998	5,109	Rt	4,576	L	18,659	16,740	(1,919)	-11%
Jul-1998	4,408	Rt	4,020	L	20,132	18,494	(1,638)	-9%
Aug-1998	4,267	Rt	3,983	L	16,529	15,561	(968)	-6%
Sep-1998	3,938	Rt	3,798	L	11,252	12,203	951	8%
Oct-1998	4,972	G	4,738	G	8,506	9,742	1,236	13%
Nov-1998	5,371	G	4,909	G	6,541	7,546	1,005	13%
Dec-1998	5,268	G	4,881	G	6,044	7,142	1,098	15%
Jan-1999	5,010	G	4,628	G	7,008	7,909	901	11%
Feb-1999	4,687	G	4,467	G	14,340	14,883	543	4%
Mar-1999	5,363	G	5,117	G	17,379	17,743	364	2%
Apr-1999	5,511	G	5,512	G	11,869	11,532	(337)	-3%
May-1999	4,973	G	4,637	G	15,014	13,830	(1,184)	-9%
Jun-1999	4,581	G	4,471	G	16,689	16,252	(437)	-3%
Jul-1999	4,230	G	4,380	G	16,986	17,068	82	0%
Aug-1999	3,648	G	3,960	G	14,465	15,596	1,131	7%
Sep-1999	4,234	G	4,094	G	8,863	9,890	1,027	10%
Oct-1999	5,423	Rt	4,482	G	6,341	8,329	1,988	24%
Nov-1999	4,693	Rt	4,253	G	6,010	7,334	1,324	18%
Dec-1999	4,853	Rt	4,383	G	4,957	6,177	1,220	20%
Jan-2000	4,158	Rt	4,355	G	5,359	7,520	2,161	29%
Feb-2000	4,554	S	4,622	G	14,089	14,844	755	5%
Mar-2000	5,051	S	5,047	G	16,353	16,916	563	3%
Apr-2000	4,669	S	4,863	G	12,283	13,037	754	6%
May-2000	4,150	S	4,238	G	12,137	12,157	20	0%
Jun-2000	4,269	S	4,190	G	16,253	15,313	(940)	-6%
Jul-2000	4,017	S	3,899	G	15,378	14,344	(1,034)	-7%
Aug-2000	3,669	S	3,485	G	13,241	12,180	(1,061)	-9%
Sep-2000	4,230	S	3,792	G	6,967	6,843	(124)	-2%

	average	average	totals	totals		
WY 1997	4,477	4,257	176,433	167,739	(8,694)	-5%
WY 1998	4,625	4,439	195,263	205,104	9,841	5%
WY 1999	4,821	4,650	143,705	149,133	5,428	4%
WY 2000	4,478	4,301	129,368	134,994	5,626	4%

Data Source:
- G — US Geological Survey
- L — Lawrence Berkeley Laboratory
- Rt — Calculated from Regional Board data
- S — San Luis & Delta-Mendota Water Authority

Table 3. Comparison of Selenium Measurements

	Flow-weighted Concentration				Loads					
	Station A µg/L		Station B µg/L		Station A lbs/month		Station B lbs/month		Difference	Percent of Station B
Oct-1996	60.6	Rr	58.3	R	223	Rr	202	R	(21)	-10%
Nov-1996	59.2	Rr	59.0	R	232	Rr	252	R	21	8%
Dec-1996	83.2	Rr	53.9	R	412	Rr	285	R	(127)	-44%
Jan-1997	84.3	Rr	59.5	R	877	Rr	599	R	(278)	-46%
Feb-1997	86.9	Rr	77.3	R	1,030	Rr	878	R	(152)	-17%
Mar-1997	77.1	Rr	84.4	R	1,076	Rr	1,119	R	43	4%
Apr-1997	101.2	Rr	105.7	R	1,272	Rr	1,280	R	8	1%
May-1997	69.8	Rr	74.1	R	817	Rr	849	R	32	4%
Jun-1997	65.9	Rr	65.0	R	583	Rr	611	R	28	5%
Jul-1997	49.8	Rr	48.0	R	441	Rr	428	R	(13)	-3%
Aug-1997	42.6	Rr	40.5	R	354	Rr	348	R	(6)	-2%
Sep-1997	30.7	Rr	27.7	R	116	Rr	109	R	(7)	-6%
Oct-1997	62.3	Rr	51.9	R	226	Rr	248	R	22	9%
Nov-1997	69.4	Rr	48.9	R	188	Rr	207	R	19	9%
Dec-1997	65.4	Rr	46.6	R	190	Rr	178	R	(12)	-7%
Jan-1998	84.2	Rr	86.7	R	282	Rr	335	R	54	16%
Feb-1998	45.3	Rr	50.8	R	843	Rr	965	R	122	13%
Mar-1998	75.2	Rr	82.8	R	1,447	Rr	1,600	R	153	10%
Apr-1998	107.1	Rr	103.1	R	1,585	Rr	1,550	R	(35)	-2%
May-1998	93.7	Rr	103.0	R	1,201	Rr	1,370	R	169	12%
Jun-1998	83.0	Rr	81.6	R	819	Rr	807	R	(12)	-2%
Jul-1998	48.8	Rr	49.5	R	603	Rr	615	R	12	2%
Aug-1998	46.3	Rr	47.4	R	485	Rr	500	R	15	3%
Sep-1998	48.5	Rr	44.7	R	374	Rr	388	R	14	4%
Oct-1998	63.7	Rr	49.5	Rr	295	Rr	277	R	(18)	-6%
Nov-1998	67.9	Rr	53.2	Rr	224	Rr	226	R	2	1%
Dec-1998	82.6	Rr	61.0	Rr	257	Rr	239	R	(18)	-7%
Jan-1999	73.9	Rr	62.1	Rr	280	Rr	284	R	4	1%
Feb-1999	77.5	Rr	67.0	Rr	641	Rr	609	R	(32)	-5%
Mar-1999	95.3	Rr	85.9	Rr	833	Rr	799	R	(34)	-4%
Apr-1999	96.1	Rr	90.2	Rr	559	Rr	529	R	(30)	-6%
May-1999	59.5	Rr	60.3	Rr	485	Rr	482	R	(3)	-1%
Jun-1999	53.7	Rr	53.3	Rr	530	Rr	524	R	(6)	-1%
Jul-1999	43.2	Rr	43.8	Rr	469	Rr	462	R	(7)	-1%
Aug-1999	40.4	Rr	39.1	Rr	433	Rr	418	R	(15)	-4%
Sep-1999	44.6	Rr	41.8	Rr	252	Rr	275	R	23	8%
Oct-1999	53.7	Rr	35.1	R	170	Rr	181	R	11	6%
Nov-1999	56.1	Rr	41.4	R	194	Rr	193	R	(1)	-1%
Dec-1999	88.1	Rr	61.9	R	243	Rr	236	R	(7)	-3%
Jan-2000	80.0	Rr	61.0	R	279	Rr	285	R	6	2%
Feb-2000	101.0	Rr	62.3	R	595	Rr	541	R	(54)	-10%
Mar-2000	96.8	Rr	84.0	R	782	Rr	761	R	(21)	-3%
Apr-2000	92.9	Rr	75.8	R	576	Rr	549	R	(27)	-5%
May-2000	49.4	Rr	55.1	R	391	Rr	427	R	36	9%
Jun-2000	43.2	Rr	44.4	R	444	Rr	439	R	(5)	-1%
Jul-2000	41.8	Rr	42.7	R	432	Rr	425	R	(7)	-2%
Aug-2000	34.1	Rr	34.3	R	333	Rr	324	R	(9)	-3%
Sep-2000	51.6	Rr	49.7	R	230	Rr	242	R	12	5%

	averages	averages	totals	totals		
WY 1997	67.6	62.8	7,431	6,960	(471)	-6%
WY 1998	69.1	66.4	8,244	8,763	519	6%
WY 1999	66.5	58.9	5,257	5,124	(133)	-3%
WY 2000	65.7	54.0	4,669	4,603	(65)	-1%

Revised: 03/30/2001

References:

R CVRWQCB sum of daily load values

Rr Flow-weighted averages calculated from CVRWQCB data

Table 4. Grassland Bypass Project — San Luis Drain Discharge Balance

Month	CIMIS ETo				Evaporation (Kc=1.1)		Water Loss to Evap	Water Gain from Precip	Gain or loss from water surface	Site A	Site B	B-A	Net Water Gain Loss	Equivalent Flowrate	Percent of Discharge
	Panoche	Telles	Los Banos	Average	inches	feet	acre feet	acre feet	acre feet	acre feet	acre feet	acre feet	acre feet	cfs	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Oct-1999	4.26	4.28	3.76	4.10	4.51	0.38	38.3	0.0	-38.3	1,162	1,850	688	726	12	39%
Nov-1999	2.02	1.97	1.63	1.87	2.06	0.17	17.5	2.1	-15.4	1,273	1,710	438	453	8	26%
Dec-1999	1.78	1.81	1.42	1.67	1.84	0.15	15.6	0.5	-15.1	1,015	1,400	385	400	7	29%
Jan-2000	1.12	1.12	0.86	1.03	1.14	0.09	9.6	13.0	3.4	1,281	1,720	439	436	7	25%
Feb-2000	1.48	1.54	1.36	1.46	1.61	0.13	13.6	17.3	3.7	3,074	3,190	116	112	2	4%
Mar-2000	4.04	4.15	3.9	4.03	4.43	0.37	37.6	3.5	-34.1	3,217	3,330	113	147	2	4%
Apr-2000	5.46	5.66	5.25	5.46	6.00	0.50	50.9	9.6	-41.3	2,614	2,660	46	87	1	3%
May-2000	7.74	7.6	6.87	7.40	8.14	0.68	69.1	0.8	-68.3	2,906	2,850	(56)	12	0	0%
Jun-2000	8.57	8.5	8.34	8.47	9.32	0.78	79.0	0.8	-78.2	3,783	3,630	(153)	(75)	(1)	-2%
Jul-2000	8.04	8.28	8.34	8.22	9.04	0.75	76.7	0.0	-76.7	3,804	3,660	(144)	(67)	(1)	-2%
Aug-2000	7.2	7.37	7.4	7.32	8.06	0.67	68.3	0.2	-68.1	3,586	3,470	(116)	(48)	(1)	-1%
Sep-2000	5.22	5.41	5.25	5.29	5.82	0.49	49.4	0.3	-49.1	1,637	1,790	154	203	3	11%

Table Prepared by Summers Engineering, February 2001.

Notes

(1) - (3)	CIMIS base evapotranspiration in inches
(4)	Average of (1) through (3)
(5) & (6)	Evaporation calculated from ETo. Kc value based on UC Extension leaflet 21427
(7)	(6)xSLD surface area. SLD surface area = 28 mi x 30' top width = 101.8 ac
(8)	Monthly CIMIS precipitation (Tellis, Panoche, and Los Banos) applied to SLD surface area
(9)	(8)-(7)
(10)	Site A discharge in acre feet
(11)	Site B discharge in acre feet
(12)	(11)-(10)
(13)	(12)-(9)
(14)	Average daily flowrate (cfs) of the Net Water Gain
(15)	(13)/(11)x100%

Figure 3a. Comparison of Selenium Loads in the San Luis Drain (2000 Water Year)

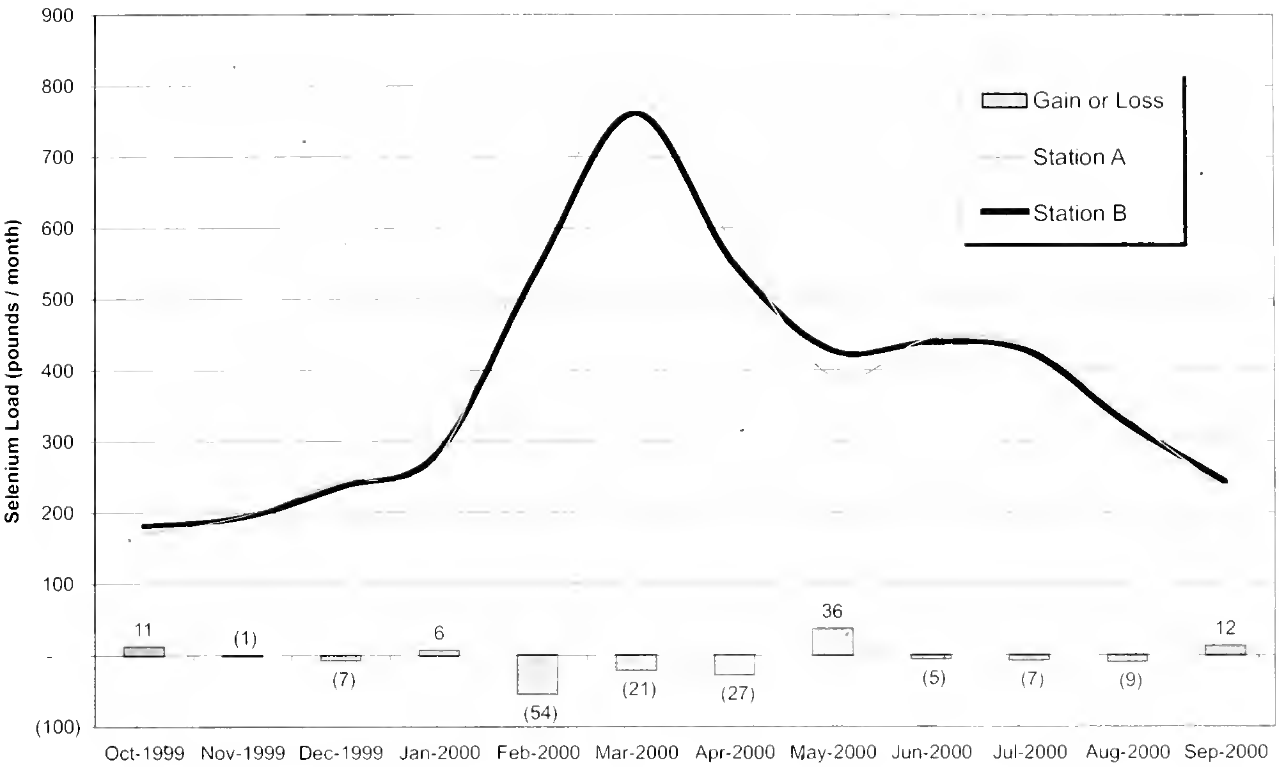
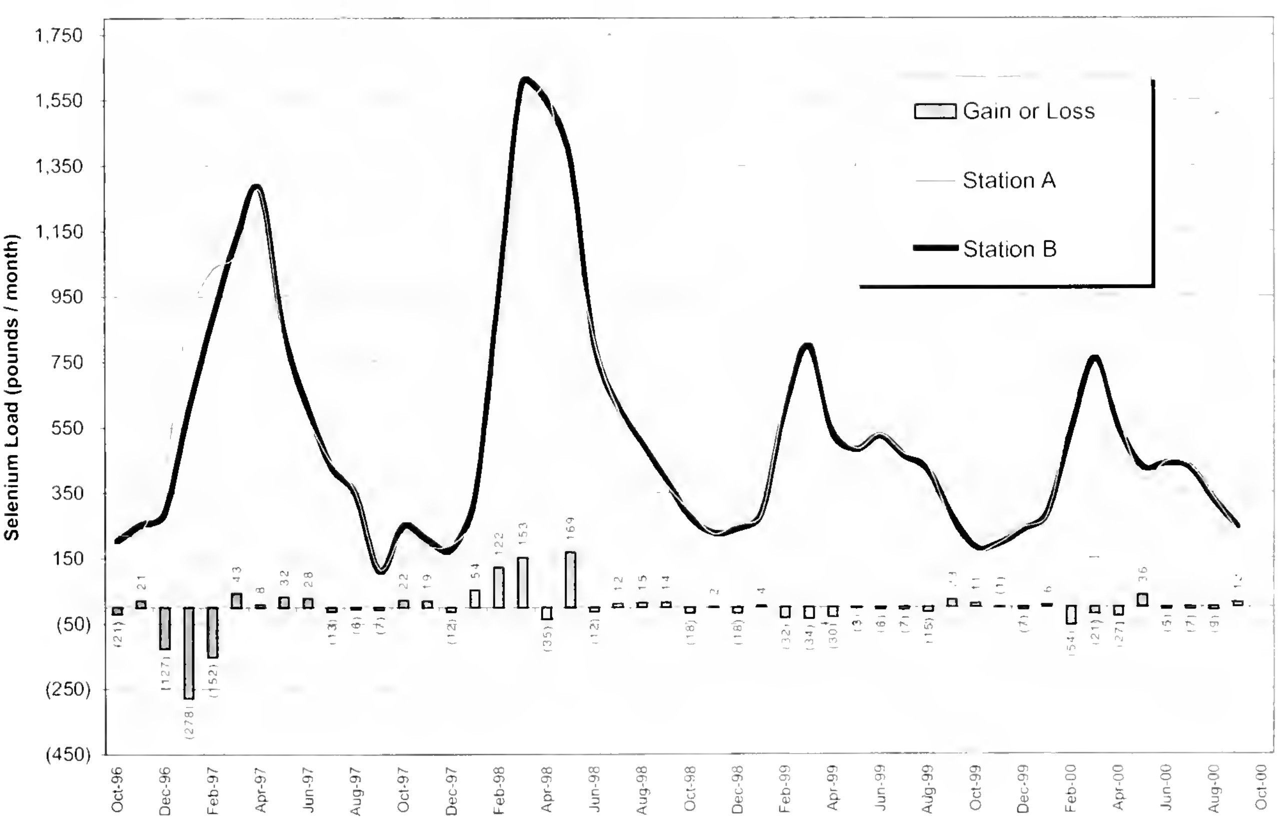


Figure 3b. Comparison of Selenium Loads in the San Luis Drain (1996–2000 Water Years)



Flow data, when combined with continuous and discrete selenium data, are used to compute this mass balance. However, selenium sampling does not occur at the same frequency at both Stations A and B.

During WY 2000, selenium samples were collected by auto-samplers at both sites. At Station B, seven 85 ml samples were collected each day; the composite of each day's samples were analyzed in the laboratory. At Station A, seven daily samples were mixed to produce a single weekly composite for analysis. In addition, weekly grab samples were collected at both sites for comparison.

Figure 3a shows the monthly loads of selenium at both sites during WY 2000. Figure 3b shows the loads for the four years of the GBP. Table 3 lists the monthly loads of selenium in water passing both stations for all four years of the Project.

During WY 2000, less selenium flowed past Station B than Station A. The load of selenium measured in water passing Station A was 4,669 pounds, and at Station B, 4,603 pounds. The load of selenium increased in October, January, May, and September by 65 pounds. The load decreased during the other months by about 130 pounds. This indicates an annual net loss of selenium between the sites of 65 pounds or a net reduction of 1%.

The reduction of selenium between the sites may be due to measurement error, microbial uptake, adsorption to sediments, volatilization, or seepage from the SLD between the sites. The increase of selenium may be due to measurement error or seepage of seleniferous water into the SLD between Stations A and B.

Conclusions

In WY 1998, 1999, and 2000, there has been a 5 to 7% increase in water in the San Luis Drain during autumn and winter months when adjacent wetlands are flooded. An increase in salt of 4 to 5% also occurred during these Water years. A decrease in selenium occurred in WY 1999 and 2000.

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Introduction

The purpose of this chapter is to compare the loads of salt discharged by the Grassland Bypass Project (GBP) with loads that might exist in the absence of the Project. This comparison uses flow and salinity data for Stations B, D, F, and N from October 1985 to September 2000. Two methods are used:

1. simple comparison of flow and salt loads as percentages, and
2. a theoretical dilution analysis.

The theoretical dilution analysis was agreed upon in meetings involving the US Bureau of Reclamation, the South Delta Water Agency and its legal counsel, and the California Regional Water Quality Control Board, as a means of demonstrating that the Project was not causing adverse downstream impacts. This analysis was not specified in the Compliance Monitoring Program (USBR, 1996) or the Quality Assurance Project Plan (Entrix, 1997). Work continues to standardize the methodologies used to calculate loads and the theoretical dilution.

Note that historical concentration and load values have been updated and differ from those in the WY 1999 annual report and errata sheets.

The 1995 Agreement for Use of the San Luis Drain includes the following statement:

> "It is the objective and intention of RECLAMATION and the AUTHORITY, among other things, to ensure that the use of the Drain as provided in this Agreement does not result in degradation of water quality in the San Joaquin River relative to the quality that would exist in the absence of the Project and does not reduce the ability to meet the salinity standard at Vernalis compared to the ability to meet the salinity standard that would exist in the absence of the Project." (USBR, et. al., 1995)

Comparison of Flow and Salt Loads as Percentages

Table 1 compares the monthly flows and loads of salt discharged by the GBP with those in the San Joaquin River at Crows Landing. Though the GBP contributed 3% of the flows in the river as measured at Crows Landing, that discharge contained 19% of the salts during WY 2000.

Tables 2a, 2b, and 2c compare the volumes of water discharged from the 97,000 acre Grassland Drainage Area (GDA) with flow in the Mud and Salt Slough watershed. During the WY 2000, 31,260 acre-feet of water were discharged from the GDA, which was approximately 13% of the 235,500 acre-feet that flowed from the region. The WY 2000 volume was about 37% less than the average annual volume of drainage water discharged prior to the GBP (31,260 acre-feet vs. 49,760 acre-feet).

Tables 3a, 3b, and 3c compare the loads of salts discharged from the GDA with the salts in Mud and Salt Sloughs. During the WY 2000, 135,000 tons of salt were discharged from the GDA, which was almost 36% of the 372,000 tons that left the region as measured by summing Mud and Salt Slough salt loads. The WY 2000 salt load was about 29% less than the average annual salt load discharged prior to the GBP (135,000 tons vs. 191,000 tons) between WY 1986 and WY 1996. The WY 2000 regional salt load was about 4% less than the average annual salt load discharged prior to the GBP (372,453 tons versus 388,254 tons).

Theoretical Dilution of GBP Discharges to Meet Vernalis Standards

In order to assess the effect of GBP on salinity in the San Joaquin River, an analysis was developed to theoretically isolate the effects of GBP from other activities potentially affecting salinity concentrations in the river. Drainage from GBP was assumed as the only drainage relevant to Project-related changes in salt load on the San Joaquin River. The analysis was cast in terms of theoretical dilution water needed to bring the GBP discharges to the Vernalis seasonal EC objectives.

The salinity objectives for Vernalis are 1,000 μS/cm (640 mg/L) in the winter months (September-March) and 700 μS/cm (448 mg/L) in the summer months (April-August).

Figure 1 shows the theoretical volume of water that would be needed to dilute the combined salt loads from the GDA, measured at Station B, and the regional watershed, drained by Mud Slough and Salt Slough (Stations D & F), to meet the Vernalis standards. This analysis does not take into account any of the other operational criteria, nor does it consider salinity contributions to the river other than those derived from the GDA. The value of the analysis is that it permits a "with"

Table 1. Comparison of Flows and Salt Loads Discharged by the Grassland Bypass Project to the San Joaquin River (WY 1997–2000)

	Flow					Salt Load		
	Discharged from GDA		San Joaquin River at Crows Landing			Discharged from GDA	San Joaquin River at Crows Landing	
	Station B		Station N		B as % of N	Station B	Station N	B as % of N
	acre-feet		acre-feet			tons	tons	
Monthly Totals								
Oct-1996	1,276	L	62,290	G	2%	5,070	33,262	15%
Nov-1996	1,569	L	61,120	G	3%	6,048	44,792	14%
Dec-1996	1,946	L	268,300	G	1%	8,020	73,753	11%
Jan-1997	3,703	L	1,574,000	G	0%	15,433	220,954	7%
Feb-1997	4,173	L	1,299,000	G	0%	20,463	253,517	8%
Mar-1997	4,876	L	283,700	G	2%	22,913	178,110	13%
Apr-1997	4,453	L	80,480	G	6%	24,111	73,128	33%
May-1997	4,215	L	76,100	G	6%	20,063	58,784	34%
Jun-1997	3,457	L	35,980	G	10%	16,153	42,186	38%
Jul-1997	3,277	L	35,850	G	9%	13,873	35,876	39%
Aug-1997	3,159	L	37,630	G	8%	11,117	41,729	27%
Sep-1997	1,445	L	29,820	G	5%	4,474	24,611	18%
Oct-1997	1,756	L	39,860	G	4%	7,819	34,861	22%
Nov-1997	1,558	L	44,690	G	3%	6,594	49,011	13%
Dec-1997	1,406	L	53,260	G	3%	6,221	60,705	10%
Jan-1998	1,421	L	139,600	G	1%	7,036	80,603	9%
Feb-1998	6,993	L	1,001,000	G	1%	23,906	360,319	7%
Mar-1998	7,106	L	623,100	G	1%	34,244	266,927	13%
Apr-1998	5,527	L	832,100	G	1%	29,250	238,007	12%
May-1998	4,890	L	743,600	G	1%	27,036	152,762	18%
Jun-1998	3,635	L	707,300	G	1%	16,740	109,320	15%
Jul-1998	4,572	L	502,700	G	1%	18,494	69,341	27%
Aug-1998	3,883	L	108,100	G	4%	15,561	47,242	33%
Sep-1998	3,193	L	109,600	G	3%	12,203	42,371	29%
Oct-1998	2,040	G	128,600	G	2%	9,742	44,509	22%
Nov-1998	1,530	G	73,090	G	2%	7,546	52,300	14%
Dec-1998	1,450	G	95,490	G	2%	7,142	52,295	14%
Jan-1999	1,700	G	96,020	G	2%	7,909	64,734	12%
Feb-1999	3,310	G	161,500	G	2%	14,883	82,991	18%
Mar-1999	3,450	G	113,600	G	3%	17,743	101,750	17%
Apr-1999	2,080	G	115,200	G	2%	11,532	72,955	16%
May-1999	2,960	G	84,070	G	4%	13,830	54,820	25%
Jun-1999	3,610	G	40,690	G	9%	16,252	44,925	36%
Jul-1999	3,870	G	34,840	G	11%	17,068	37,983	45%
Aug-1999	3,910	G	37,810	G	10%	15,596	39,320	40%
Sep-1999	2,400	G	34,440	G	7%	9,890	31,517	31%
Oct-1999	1,850	G	51,890	G	4%	8,329	38,233	22%
Nov-1999	1,710	G	52,230	G	3%	7,334	48,036	15%
Dec-1999	1,400	G	42,230	G	3%	6,177	47,265	13%
Jan-2000	1,720	G	59,110	G	3%	7,520	58,618	13%
Feb-2000	3,190	G	201,700	G	2%	14,844	90,098	16%
Mar-2000	3,330	G	274,900	G	1%	16,916	136,826	12%
Apr-2000	2,660	G	100,200	G	3%	13,037	70,370	19%
May-2000	2,850	G	84,830	G	3%	12,157	65,234	19%
Jun-2000	3,630	G	43,800	G	8%	15,313	44,821	34%
Jul-2000	3,660	G	41,610	G	9%	14,344	40,284	36%
Aug-2000	3,470	G	38,800	G	9%	12,180	35,341	34%
Sep-2000	1,790	G	36,180	G	5%	6,843	28,751	24%
Annual Totals								
WY 1997	37,550		3,844,270		1%	167,739	1,080,703	16%
WY 1998	45,939		4,904,910		1%	205,104	1,511,470	14%
WY 1999	32,310		1,015,350		3%	149,133	680,098	22%
WY 2000	31,260		1,027,480		3%	134,994	703,876	19%

Table 2a. Annual Volume of Drainage Water Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Water Year (1)		% CVP Contract Delivery (2)	Discharge from GDA (3)		Discharge from Region (4)
			acre-feet		acre-feet
WY 1986		100%	67,006		284,316
WY 1987		100%	74,902		233,843
WY 1988		100%	65,327		230,454
WY 1989		100%	54,186		211,393
WY 1990		50%	41,662		194,656
WY 1991		25%	29,290		102,162
WY 1992		25%	24,533		85,428
WY 1993		50%	41,197		167,955
WY 1994		35%	38,670		183,546
WY 1995		100%	57,574		263,769
WY 1996		95%	52,978		267,948
WY 1997	GBP	90%	37,550		287,210
WY 1998	GBP	100%	45,939		378,680
WY 1999	GBP	70%	32,310		253,130
WY 2000	GBP	65%	31,260		235,490

Table 2b. Comparison of WY 2000 Discharge Volume to Previous Years

		Discharge from GDA (3)	WY 2000 difference	Discharge from Region (4)	WY 2000 difference
		acre-feet		acre-feet	
Average, all years	1986 - 2000	46,292	-32%	225,332	5%
Prior years average	1986 - 1999	47,366	-34%	224,606	5%
Before GBP average	1986 - 1996	49,757	-37%	202,315	16%
GBP average	1997 - 2000	36,765	-15%	288,628	-18%
50 % CVP or less	1990 - 1994	35,070	-11%	146,749	60%
More than 50% CVP	1986 - 1989 1995 - 2000	54,145	-42%	260,520	-10%

Table 2c. Total Volumes of Drainage Water Table

		Discharge from GDA (3)	WY 2000 volume	Discharge from Region (4)	WY 2000 volume
		acre-feet		acre-feet	
All years	1986 - 2000	694,383	5%	3,379,980	7%
Before GBP	1986 - 1996	547,325	6%	2,225,470	11%
GBP total	1997 - 2000	147,058	21%	1,154,510	20%

Notes:

(1) Water Year - October 1 - September 30

(2) Drought Years with 50% or less CVP delivery

(3) Grassland Drainage Area

(4) Mud and Salt Sloughs

Data compiled by Nigel Quinn, LBNL, from CVRWQCB and USGS reports.

Table 3a. Annual Loads of Salt Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Water Year (1)		% CVP Contract Delivery (2)	Discharge from GDA (3)		Discharge from Region (4)
			tons		tons
WY 1986		100%	214,250		494,544
WY 1987		100%	241,526		438,904
WY 1988		100%	236,301		455,956
WY 1989		100%	202,420		389,325
WY 1990		50%	171,265		380,564
WY 1991		25%	129,899		221,542
WY 1992		25%	110,327		197,352
WY 1993		50%	183,021		336,522
WY 1994		35%	171,495		379,408
WY 1995		100%	237,530		499,339
WY 1996		95%	197,526		477,725
WY 1997	GBP	90%	167,739		446,690
WY 1998	GBP	100%	205,104		627,687
WY 1998	GBP	70%	149,133		401,616
WY 2000	GBP	65%	134,994		372,453

Table 3b. Comparison of WY 2000 Salt Loads to Previous Years

		Discharge from GDA (3)	WY 2000 difference	Discharge from Region (4)	WY 2000 difference
		Tons	percent	Tons	percent
Average, all years	1986 - 2000	183,502	-26%	407,975	-9%
Prior years average	1986 - 1999	186,967	-28%	410,512	-9%
Before GBP average	1986 - 1996	190,505	-29%	388,289	-4%
GBP average	1997 - 2000	164,243	-18%	462,112	-19%
50 % CVP or less	1990 - 1994	153,201	-12%	303,078	23%
More than 50% CVP	1986 - 1989 1995 - 2000	202,814	-33%	457,800	-19%

Table 3c. Total Salts

		Discharge from GDA (3)	WY 2000 volume	Discharge from Region (4)	WY 2000 volume
		tons	percent	tons	percent
All years	1986 - 2000	2,752,530	5%	6,119,627	6%
Before GBP	1986 - 1996	2,095,560	6%	4,271,181	9%
GBP total	1997 - 2000	656,970	21%	1,848,446	20%

Notes:

(1) Water Year - October 1 - September 30

(2) Drought Years with 50% or less CVP delivery

(3) Grassland Drainage Area

(4) Mud and Salt Sloughs

Data compiled by Nigel Quinn, LBNL, from CVRWQCB and USGS reports.

and "without" Project comparison with prior year hydrology, in terms (water quality releases from a reservoir) meaningful to water users and managers.

The assimilative capacity analysis considers the total volume of dilution water (assumed to have a salinity of 100 ppm) that would be needed to reduce the drainage water alone to the salinity objective. Note that the monthly volume of dilution water is highly dependent on the 100-ppm assumption. Note also that the relation between dilution water quality and required volume is non-linear.

Figure 1 shows the monthly dilution requirements for WY 1986 through 2000. Figure 2 shows the total dilution requirement for each water year. The unshaded areas in Figures 1 and 2 represent the dilution requirements for salt loads generated by the Mud and Salt Slough watershed which includes the GDA and other agricultural areas, wetlands, and uncontrolled runoff from the Coast Range watersheds. The shaded area in the Figures shows the dilution requirements for salt loads discharged from only the GDA.

The data for Figure 2 are summarized in Tables 4a and 4b. During the WY 2000, about 195,000 acre-feet of water would have been required to dilute the 31,260 acre-feet of drainage water discharged from the GDA. In comparison, more than 400,000 acre-feet of water would have been needed to dilute the regional discharges to meet the Vernalis standards. The WY 2000 virtual dilution requirement for the GDA is about 29% less than that required during the years prior to the implementation of the GBP. The WY 2000 theoretical dilution requirement for the region was 12% higher than that required during the years prior to implementation of the GBP.

These percentages should be put into context of the 1990 – 1994 drought and the initiation of CVPIA deliveries to wetlands (private, State and Federal) in the Grasslands Basin that preceded the authorization of the Grassland Bypass Project. The latter has profoundly affected the hydrology of the Grasslands Basin and has affected the timing of salt loading to the San Joaquin River.

Drought occurred during the WY 1990 to 1994 when 50% or less of the contracted supplies of water were delivered to federal contractors in the San Luis Unit and Delta Division of the CVP.

Data for the GDA for WY 1986 to 2000 show that in WY 1999 and WY 2000, the salt loads (Tables 3a and 3b) and theoretical dilution requirements (Tables 4a and 4b, and Figures 1 and 2) were smaller than in all other years with the exception of the drought years of WY 1991 and 1992.

The theoretical dilution required for the entire region in WY 2000 was larger than the average of all prior years and similar to the average of above normal and wet years with CVP deliveries above 65% (Table 4b).

Both WY 1999 and 2000 had no unusual or unexpected hydrologic events as occurred in WY 1997 and WY 1998. Irrigation deliveries were 65 to 70% of contracted supplies lower than the previous two yeas of the Project (Table 2a).

Data for several more years will be necessary before the impact of the GBP can be quantified with confidence.

The formula for theoretical dilution is:

$Q_2 = Q_1(C_3 - C_1)/(C_2 - C_3)$

Q_1 = Drainwater discharge in acre-feet per month

Q_2 = Volume of water needed to dilute Q_1 to meet Vernalis standards in acre-feet per month

C_1 = Measured concentration of GBP drainage water in parts per million (mg/L)

C_2 = Assumed concentration of dilution water = 100 mg/L

C_3 = Vernalis standard concentration = 448 mg/L April - August 640 mg/L September - March

Entrix, Inc. 1997. Quality Assurance Project Plan for the Compliance Monitoring Program for the Use and Operation of the Grassland Bypass Project (Final Draft). Prepared for the U.S. Bureau of Reclamation. Sacramento, CA. June 20, 1997.

U.S. Bureau of Reclamation and the San Luis & Delta-Mendota Water Authority. 1995. Agreement for Use of the San Luis Drain. Agreement No. 6-07-20-w1319, November 3, 1995.

U.S. Bureau of Reclamation, et. al. September 1996. Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project, September 1996. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

Figure 1. Monthly Volumes of Water Needed to Dilute Drainage Water from the Grassland Drainage Area and Regional Watershed to Meet Vernalis Standards (WY 1986–2000)

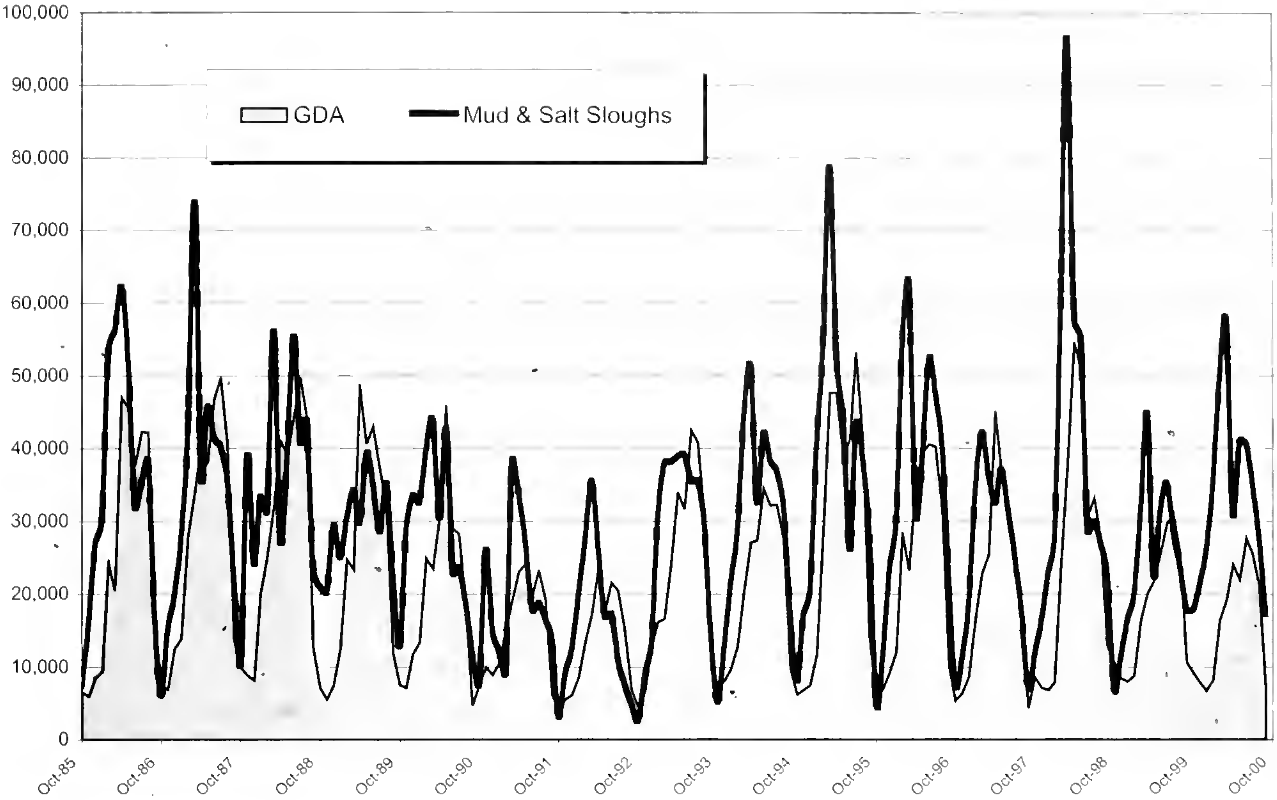
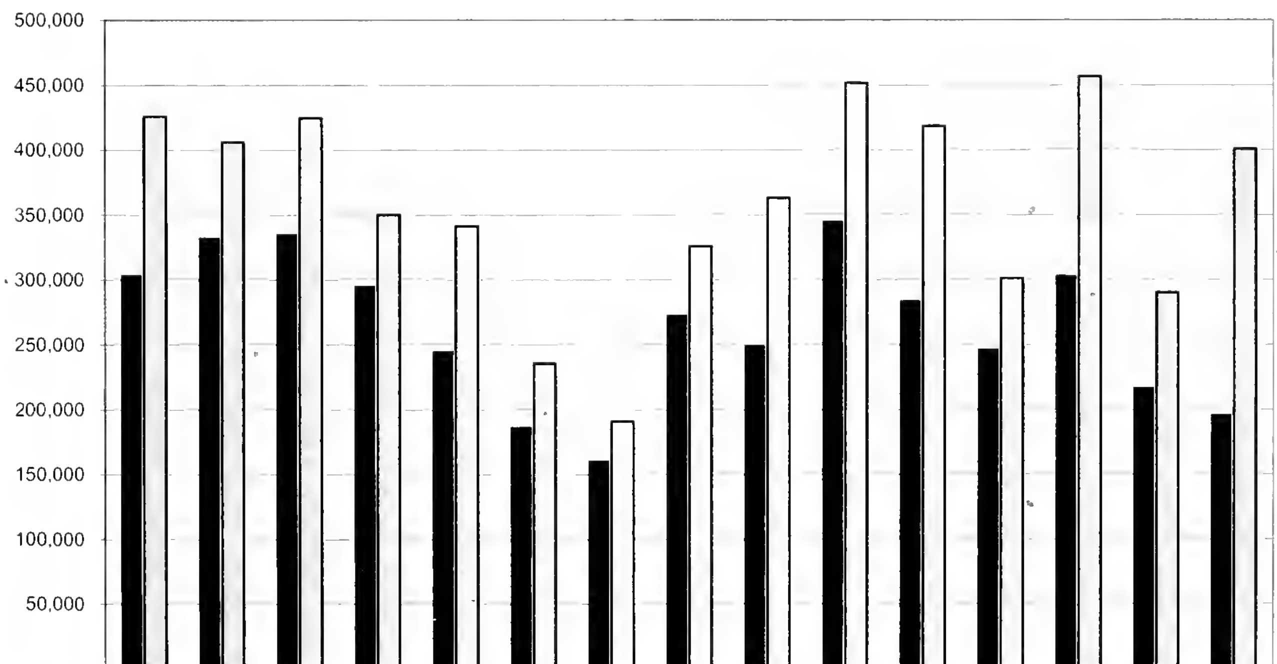


Figure 2. Annual Volumes of Water Needed to Dilute Drainage from the Grassland Drainage Area and the Regional Watershed to Meet Vernalis Standards (WY 1986–2000)



	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
■ GDA	303,361	332,189	335,151	294,834	245,167	186,454	160,419	272,851	249,057	344,983	283,339	246,094	302,996	216,577	195,422
□ Regional	426,147	406,134	424,453	350,406	341,299	235,849	191,068	325,964	363,094	451,505	418,393	301,219	456,678	290,092	400,730

Table 4a. Annual Volumes of Dilution Water Needed to Meet Vernalis Standards

Water Year (1)		% CVP Contract Delivery (2)	Water Needed to Dilute Drainage from GDA to Meet Vernalis Standard (3)		Water Needed to Dilute Drainage from Region to Meet Vernalis Standard (4)
			acre-feet		acre-feet
WY 1986		100%	303,361		426,147
WY 1987		100%	332,189		406,134
WY 1988		100%	335,151		424,453
WY 1989		100%	294,834		350,406
WY 1990		50%	245,167		341,299
WY 1991		25%	186,454		235,849
WY 1992		25%	160,419		191,068
WY 1993		50%	272,851		325,964
WY 1994		35%	249,057		363,094
WY 1995		100%	344,983		451,505
WY 1996		95%	283,339		418,393
WY 1997	GBP	90%	246,094		301,219
WY 1998	GBP	100%	302,996		456,678
WY 1999	GBP	70%	216,577		290,092
WY 2000	GBP	65%	195,422		400,730

Table 4b. Comparison of Dilution Requirements

		Water Needed to Dilute Drainage from GDA to Meet Vernalis Standard (3)	WY 2000 difference	Water Needed to Dilute Drainage from Region to Meet Vernalis Standard (4)	WY 2000 difference
		acre-feet	percent	acre-feet	percent
Average	1986 - 2000	264,593	-26%	358,869	12%
Prior years average	1986 - 1999	269,534	-27%	355,879	13%
Before GBP	1986 - 1996	273,437	-29%	357,665	12%
GBP	1997 - 2000	240,272	-19%	362,180	11%
50% CVP or less	1990 - 1994	222,790	-12%	291,455	37%
More than 50% CVP	1986 - 1989 1995 - 2000	290,643	-33%	394,110	2%

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Abstract

In the fourth year of operation of the Grassland Bypass Project (GBP), contaminant concentrations in biota affected by the GBP rose significantly compared to the previous year in the late summer season when bioaccumulation reaches a seasonal maximum. At sampling sites in Mud Slough below the outfall of the San Luis Drain (SLD), concentrations of selenium in whole-body fish and invertebrates frequently exceeded thresholds of concern. At a backwater site well below the outfall (Site I), selenium concentrations in fish and invertebrate samples (silversides, mosquitofish, red shiners, carp, and red crayfish) exceeded toxicity thresholds in August 2000. The overall hazard of selenium to the ecosystem (Lemly's index) continued to be high in this portion of Mud Slough.

At a site further downstream in Mud Slough just above discharge into the San Joaquin River (Site E), selenium concentrations in whole-body fish also showed cyclic seasonal variation in Water Years (WY) 1999 and 2000, with concentrations in August nearing or exceeding the toxicity threshold.

In Salt Slough, where drainwater has been removed by the GBP, average selenium concentrations in fish and invertebrates have remained at-no-effect levels since the latter half of 1998. Lemly's index of selenium hazard to the Salt Slough aquatic ecosystem remained low in WY 2000 after having dropped substantially in WY 1999.

Concentrations of selenium in whole-body fish (mainly mosquitofish and bluegill) in the San Joaquin River upstream of drainage discharge (Site G) remained below the level of concern threshold (4 ppm, dry wt). Concentrations of selenium in whole-body fish (mainly mosquitofish and bluegill) in the San Joaquin River downstream of drainage discharge (Site H) have significantly increased since WY 1999. Average levels remained below the threshold of concern, but exceeded the concentration at which young salmon suffer significant adverse effects (2.7 ppm, dry weight). Selenium concentrations in all invertebrates collected from both San Joaquin River sites during the fourth year of GBP operation remain below the threshold of concern level (3 ppm, dry wt) for invertebrates as prey items. However, at Site H an insufficient number of invertebrates were available for sampling in August, as was the case in August 1999.

In WY 2000, selenium levels in gamefish muscle (only carp) at Sites E, G, and H were below the 2-ppm, wet weight, limited consumption guideline. Fish community assessment showed native fish represented 2.5% of the catch by number and 28% of the catch by species. The Sacramento blackfish was the most commonly caught native fish, probably due to its tolerance of poor water quality.

The selenium concentrations in all bird eggs were within the no effect range, but eggs collected from the vicinity of Mud Slough were elevated compared to baseline eggs collected at the Merced National Wildlife Refuge.

Selenium concentrations in seeds collected in WY 2000 and in archived seeds were below the dietary threshold of concern, but plants collected along Mud Slough had higher concentrations of selenium than those at Sites C and F.

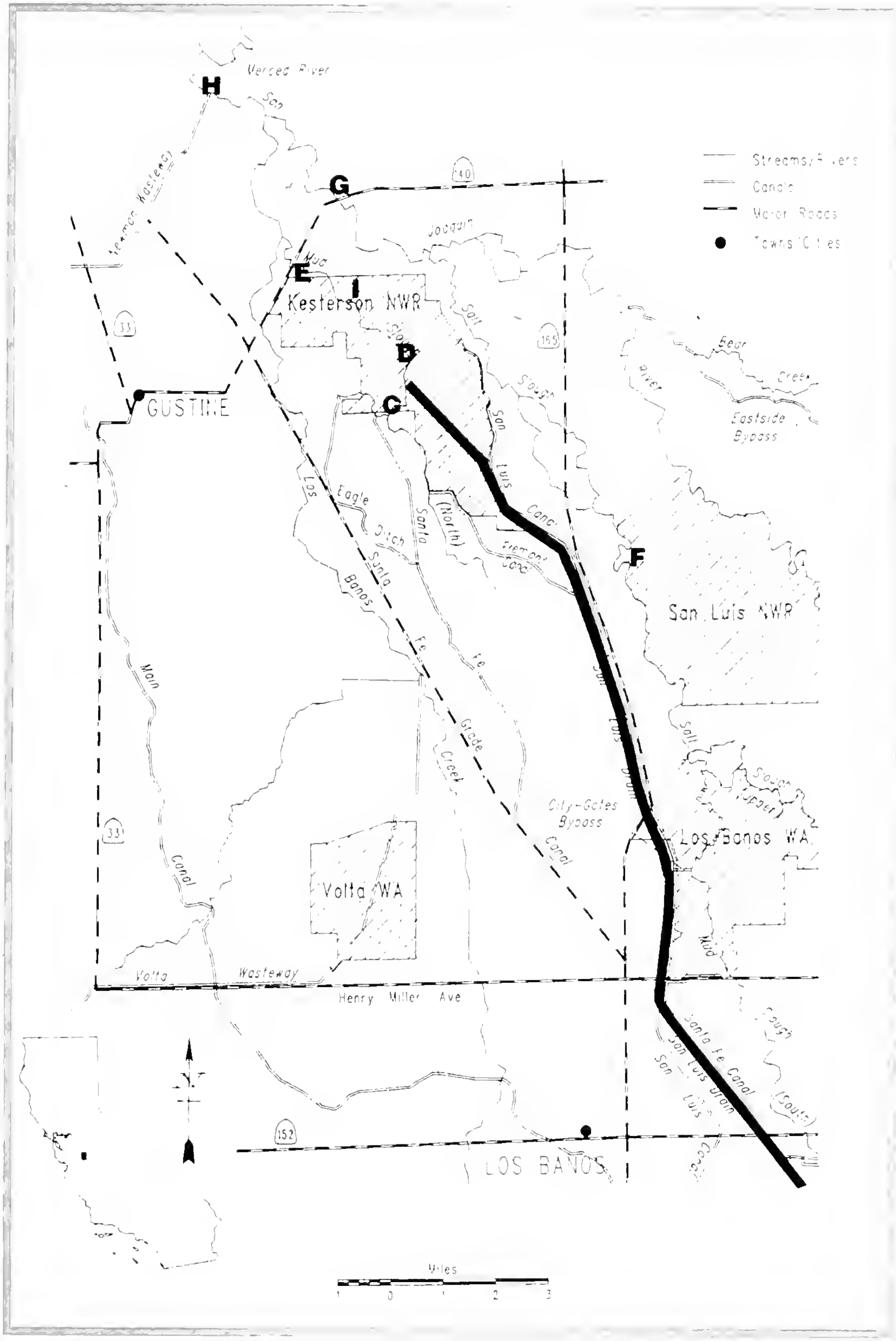
Introduction

Project History

In 1985 the SLD was closed due to deaths and developmental abnormalities of waterbirds at a reservoir in the Kesterson National Wildlife Refuge at the terminus of the SLD. The SLD, constructed by the U.S. Bureau of Reclamation (USBR), had been conceived as a means to dispose of agricultural drainwater generated from irrigation with water supplied by the federal Central Valley Water Project. However, due to environmental concerns and budget constraints, the SLD had never been completed as originally planned. The constructed portion of the SLD had been used only to convey subsurface agricultural drainwater from the Westlands Water District in the western San Joaquin Valley. Farms in the adjacent Grassland area never used the SLD, but discharged subsurface drainwater through wetland channels in the San Luis National Wildlife Refuge Complex and the China Island Unit of the North Grasslands Wildlife Area (Refuges) to the San Joaquin River. This drainwater contains elevated concentrations of selenium, boron, chromium, and molybdenum, and high concentrations of various salts (CEPA, 2000) that disrupt the normal ionic balance of affected aquatic ecosystems (SJVDP, 1990b). In addition, unknown concentrations of agricultural chemical residues (fertilizers and pesticides that do not readily adsorb to soil) may contaminate this drainwater.

Discharge from Grassland area farms was unaffected by the closure of the SLD, and drainage continued to contaminate Refuge water delivery channels after the closure of Kesterson Reservoir. To address this problem, a proposal to use a portion of the SLD and extend it to Mud Slough, a natural waterway in the Refuges, was implemented by the USBR in September 1996 with

Figure 1. Grassland Bypass Project Biota Monitoring Sites



support from other federal and state agencies (USBR, 1995; USBR and SL&D-MWA 1995; USBR et al., 1995). This project, known as the Grassland Bypass Project (GBP), diverts agricultural drainwater from Grassland area farms into the lower 28 miles of the SLD and thence into the lower portion of Mud Slough (about six miles). The GBP has removed drainwater from more than 90 miles of wetland water supply channels, including Salt Slough, and allows the Refuges full use of water rights to create and restore wetlands on the Refuges. The GBP, as currently implemented, continues to adversely affect the northernmost six miles of Mud Slough and the reach of the San Joaquin River between Mud Slough and the Merced River. However, as phased-in load reduction goals are achieved by water districts, these adverse effects are expected to be reduced. An essential component of the GBP is a monitoring program that tracks contaminant levels and effects in water, sediment, and biota to ensure that the overall effect of the GBP is not a net deterioration of the ecosystems in the area affected by the GBP.

Contaminants of Concern

In the aftermath of the deaths and developmental abnormalities of birds at Kesterson Reservoir in the early 1980s, studies definitively traced the cause to selenium in the agricultural subsurface drainwater in the reservoir (Suter, 1993). Because of this, and because of the well-known history of death, teratogenesis, and reproductive impairment caused by selenium in agricultural drainwater elsewhere (reviewed in Skorupa, 1998), the primary contaminant of concern in this monitoring program is selenium. Other inorganic constituents of potential toxicological interest in drainage water include boron, molybdenum, arsenic and chromium (Klasing and Pilch, 1988; SJVDP, 1990a; RWQCBCVR, 1998).

Selenium Ecological Risk Guidelines

The assessment of the risks that selenium poses to fish and wildlife can be difficult due to the complex nature of selenium cycling in aquatic ecosystems (Lemly and Smith, 1987). Early assessments developed avian risk thresholds through evaluating bird egg concentrations and relating those to levels of teratogenesis (developmental abnormalities) and reproductive impairment (Skorupa and Ohlendorf, 1991). In 1993, to evaluate the risks of the Grassland Bypass Project on biotic resources in Mud and Salt Sloughs, a set of ecological risk guidelines based on selenium in water, sediment, and residues in several biotic tissues were developed by a subcommittee of the San Luis Drain Re-Use Technical Advisory Committee (CAST, 1994; Engberg, et.al., 1998). These guidelines as recently modified (Table 1) are based on a large number of laboratory and field studies, most of which are summarized in Skorupa et al. (1996) and Lemly (1993). In areas where the potential for selenium exposure to fish and wildlife resources exists, site-specific selenium risk guidelines can be used to trigger appropriate actions by resource managers, regulatory agencies, and dischargers. For the GBP the selenium risk guidelines have been divided into three levels: no effect, level of concern, and toxicity. In the no effect range risks to sensitive species are not likely. As new information becomes available it should be evaluated to determine if the no effect level should be adjusted. Since the potential for selenium exposure exists, periodic monitoring of water and biota is appropriate.

Within the level of concern range there may be risk to sensitive species, and contaminant concentrations in water, sediment, and biota should be monitored on a regular basis. Immediate actions to prevent selenium concentrations from increasing should be evaluated and implemented if appropriate. Long-term actions to reduce selenium risks should be developed and implemented. Research on effects on sensitive or listed species may be appropriate.

Within the toxicity range, adverse affects are more likely across a broader range of species, and sensitive or listed species would be at greater risk. These conditions will warrant immediate action to reduce selenium exposure through disruption of pathways, reduction of selenium loads, or other appropriate actions. More detailed monitoring, studies on site-specific effects, and studies of pathways of selenium contamination may be appropriate and necessary. Long-term actions to reduce selenium risks should be developed and implemented.

The guidelines (except those for avian eggs) are intended to be population based. Therefore they should be used for evaluating population means rather than contaminant concentrations in individuals.

Warmwater Fish

The warmwater fish guidelines (Table 1) refer to concentrations of selenium in warmwater fish that adversely affect the fish themselves. The original 1993 fish guidelines have been replaced by explicitly "warmwater fish" guidelines in recognition of the evidence from the literature that coldwater fish (salmon and trout) are more sensitive to selenium than warmwater fish and that GBP monitoring data available are limited to warmwater fish. Although a coldwater fish guideline is not proposed here, a discussion of selenium effects on coldwater fish is

Table 1. Recommended Ecological Risk Guidelines for Selenium Concentrations.

Medium	Effects on	Units	No Effect	Level of Concern	Toxicity
Warmwater Fish (whole body)	fish growth condition survival	mg/kg (dry weight)	< 4	4-9	> 9
Vegetation (as diet)	bird reproduction	mg/kg (dry weight)	< 3	3-7	> 7
Invertebrates (as diet)	bird reproduction	mg/kg (dry weight)	< 3	3-7	> 7
Sediment	fish and bird reproduction	mg/kg (dry weight)	< 2	2-4	> 4
Water (total recoverable Se)	fish and bird reproduction (via foodchain)	µg/L	< 2	2-5	> 5
Avian egg	egg hatchability	mg/kg (dry weight)	< 6	6-10	> 10

Notes

- These guidelines, except those for avian eggs, are intended to be population based. Thus, trends in means over time should be evaluated. Guidelines for avian eggs are based on individual level response thresholds (e.g., Heinz, 1996; Skorupa, 1998).
- A tiered approach is suggested with whole body fish being the most meaningful in assessment of ecological risk in a flowing system.
- The warmwater fish (whole body) Level of Concern threshold is based on adverse effects on the survival of juvenile bluegill sunfish experimentally fed selenium enriched diets for 90 days (Cleveland et al., 1993). It is the geometric mean of the "no observable effect level" and the "lowest observable effect level."
- The Toxicity threshold for warmwater fish (whole body) is the concentration at which 10% of juvenile fish are killed (DeForest et al., 1999).
- The guidelines for vegetation and invertebrates are based on dietary effects on reproduction in chickens, quail and ducks (Wilber, 1980; Martin, 1988; Heinz, 1996).
- If invertebrate selenium concentrations exceed 6 mg/kg then avian eggs should be monitored (Heinz et al., 1989; Stanley et al., 1996).

provided in this section since the best information currently available happens to be very site-specific to the GBP.

The level of concern threshold for warmwater fish has been kept at about 4 mg/kg (all fish data are whole body, dry weight). Experimental data reported in the literature may be interpreted to support a range of thresholds around this value. In particular, bluegill sunfish dietary and waterborne toxicity data in Cleveland et al. (1993) can be used to support warmwater fish level of concern thresholds of 3.3 mg/kg, 3.4 mg/kg, 3.9 mg/kg, or 5.9 mg/kg. Bluegill sunfish are warmwater fish that are found in the sloughs in the GBP area, and the Cleveland et al. (1993) study yielded the best available data on warmwater fish toxicity applicable to GBP.

Cleveland et al. (1993) found no adverse effects after 59 days of exposure to concentrations of dietary selenium that resulted in a bluegill tissue concentration of 2.7 mg/kg (NOEC). Fifty-nine days of exposure to dietary concentrations that resulted in tissue concentrations of 4.2 mg/kg (LOEC) caused a significant increase in mortality relative to controls. Following the USEPA method (Stephan et al., 1985) employed by DeForest et al. (1999), the tissue threshold is calculated as the geometric mean of the NOEC and the LOEC. Application of the USEPA procedure to these data yields a toxicity threshold of 3.4 mg/kg. A similar analysis of a waterborne selenium exposure experiment (Cleveland et al., 1993) yields a threshold value of 3.3 mg/kg.

Other data in Cleveland et al. (1993) may be interpreted to support a threshold closer to 4 mg/kg or a threshold of 5.9 mg/kg. The experiments of Cleveland et al. (1993) suggest that selenium concentrations in fish tissues do not reach equilibrium until at least 90 days of dietary exposure (Figure 3 in Cleveland et al., 1993). This appears consistent with the finding, summarized below, that in the field, selenium concentrations in fish are best predicted by water concentrations averaged over the entire period of one to seven months prior to the date the fish is sampled. In deriving a tissue threshold, there then appears to be some support for using the relationship between dietary concentration and tissue concentration at 90 days

rather than 59 days. After 90 days of dietary exposure bluegill with a tissue selenium concentration of 3.3 mg/kg did not exhibit adverse effects that were significantly greater than controls, but bluegill with a tissue concentration of 4.6 mg/kg experienced significantly increased mortality. Bluegill with a tissue concentration of 7.5 mg/kg had three times the mortality of controls, but that difference in mortality was not statistically significant at the 95% level of confidence (Table 4 and Figure 3 in Cleveland et al., 1993). However, with 7.5 mg/kg, the condition factor (a measure of weight relative to length) of the fish was significantly worse than controls. Depending on whether or not the significant mortality at a tissue concentration of 4.7 mg/kg is treated as anomalous, the LOEC would be either 4.7 mg/kg or 7.5 mg/kg. Corresponding thresholds would be 3.9 mg/kg (geometric mean of 3.3 mg/kg and 4.6 mg/kg) or 5.9 mg/kg (geometric mean of 4.6 mg/kg and 7.5 mg/kg) respectively. Given the range of possible threshold values discussed above, the level of concern threshold of 4 mg/kg listed in Table 1 was not changed from the original 1993 threshold. However, considering that these data do not include adverse effects on reproduction which may be affected at lower concentrations, this threshold may not be fully protective of sensitive warmwater fish species.

The toxicity threshold for warmwater fish (whole body) of 9 mg/kg is recommended by DeForest et al. (1999). In the analysis of DeForest et al. (1999) the threshold represents an EC_{10}, that is, the concentration at which 10 percent of fish are affected. DeForest et al. (1999) excluded some toxicity data from their analysis that could support a lower threshold (Cleveland et al., 1993). Also, reproductive impairment may occur at lower selenium concentrations, but too few data are available to do a similar analysis on this effect. Therefore, this toxicity threshold may not be fully protective of sensitive warmwater fish species.

Coldwater Fish

Testing fall run chinook salmon from the Merced River, Hamilton et al. (1990) found that salmon fry growth was significantly reduced compared to controls after 30 and 60 days of being fed a diet (containing mosquitofish from the SLD) having a selenium concentration of 3.2 mg/kg dry weight. After 90 days of that diet, the selenium concentration in the salmon fry averaged 2.7 mg/kg whole body, dry weight. This fish tissue concentration was the lowest observable effect concentration (LOEC) The no observable effect concentration (NOEC) in salmon fry tissue was 0.8 mg/kg. Following the USEPA method (Stephan et al., 1985) employed by DeForest et al. (1999), the tissue threshold is calculated as the geometric mean of the NOEC and the LOEC. This procedure applied to the Hamilton et al. (1990) SLD data yields a threshold of 1.5 mg/kg (geometric mean of 0.8 and 2.7 mg/kg). It should be noted that this threshold may incorporate the interacting effects of other toxic constituents of drainwater that may have been assimilated by the SLD mosquitofish that were used as feed in the Hamilton et al. (1990) experiments. Furthermore, at the time of these experiments (1985), the SLD held agricultural drainwater from the Westlands, an area adjacent to the Grasslands area. Therefore, although these are the most site-specific selenium toxicity data available, these data may not perfectly match the current risk of toxicity to coldwater fish in the San Joaquin River due to agricultural drainwater from the GBP. Although the sloughs affected by the GBP have coldwater beneficial uses designated by the Central Valley Regional Water Quality Control Board, the fish community principally consists of warmwater species. A temporary barrier is installed seasonally across the San Joaquin River to exclude chinook salmon (a coldwater species) from these sloughs and from the San Joaquin River upstream of its confluence with the Merced River. Additionally, any application of the coldwater fish risk guidelines should take into account the fact that many coldwater fish are anadromous, and therefore feed in the selenium-contaminated portion of the San Joaquin River for a limited period of time — a brief period in their juvenile stage as they migrate downstream to the ocean.

A toxicity threshold for coldwater fish (whole body) of 9 mg/kg has been recommended by DeForest et al. (1999). In the analysis by DeForest et al. (1999) the toxicity threshold represents an EC_{10}, that is, the concentration at which 10 percent of fish are affected. DeForest et al. (1999) excluded site-specific and longer term data (Hamilton et al., 1990) which could support lower thresholds. For example, to derive their toxicity threshold for coldwater fish, DeForest et al. (1999) used only the 60 day growth data in Hamilton et al. (1999); they disregarded the 90 day mortality data in Hamilton et al. (1999) that would have yielded a toxicity threshold (corresponding to 10% mortality) of 1.7 mg/kg. In addition, the DeForest et al. (1999) analysis focused on growth and mortality. Reproductive impairment may occur at lower selenium concentrations, but too few data are available to do a similar analysis on this effect. Therefore, this threshold may not fully protect sensitive coldwater fish species.

Vegetation and Invertebrates

The guidelines for vegetation (as diet) and invertebrates (as diet) refer to selenium concentrations in plants and invertebrates affecting birds that eat these items. These guidelines are mainly based on experiments in which seleniferous grain or artificial diets spiked with selenomethionine were fed to chickens, quail or ducks resulting in reproductive impairment (Wilber, 1980; Martin, 1988; Heinz, 1996). The level of concern threshold for vegetation is 3 mg/kg (dry weight) and the toxicity threshold is 7 mg/kg. The invertebrate level of concern threshold and toxicity threshold are the same as those for vegetation.

Water

Fish and wildlife are much more sensitive to selenium through dietary exposure from the aquatic food chain than by direct waterborne exposure. Therefore the guidelines for water reflect water concentrations associated with threshold levels of food chain exposure (Hermanutz et al., 1990; Maier and Knight, 1994), rather than concentrations of selenium in water that directly affect fish and wildlife. The level of concern threshold is 2 µg/L and the toxicity threshold is 5 ug/L.

Sediment

As with water, the principal risk of sediment to fish and wildlife is via the aquatic food chain. Therefore the sediment guidelines are based on sediment concentrations as predictors of adverse biological effects through the food chain (USFWS, 1990; Van Derveer and Canton, 1997). The level of concern threshold for sediment (dry weight) is 2 mg/kg and the toxicity threshold is 4 mg/kg.

Bird Eggs

Bird eggs are particularly good indicators of selenium contamination in local ecosystems (Heinz, 1996). However, the interpretation of selenium concentrations in bird eggs in the GBP area is complicated by the proximity of contaminated and uncontaminated sites and by the variation in foraging ranges among bird species. Relative to the guidelines originally used for the GBP, the guidelines used here for bird eggs have been revised upward based on recent studies of hatchability of ibis, mallard, and stilt eggs (Henny and Herron, 1989; Heinz, 1996; USDI-BOR/FWS/GS/BIA, 1998). The level of concern threshold has been raised from 3 to 6 mg/kg dry weight, and the toxicity threshold has been raised from 8 to 10 mg/kg dry weight.

Selenium Ecological Risk Index

Several years after the risk guidelines were developed for the GBP, Lemly (1995, 1996) published a risk index designed to provide an estimate of ecosystem-level effects of selenium. Lemly's assessment procedure sums the effects of selenium on various ecosystem components to yield a characterization of overall hazard to aquatic life. The procedure involves determining an index of toxicity for each component, then adding these indexes together to yield a single index, often known as the Lemly Index. In contrast to the ecological risk guidelines outlined in Table 1, the component indexes of the Lemly Index are based on maximum contaminant concentrations rather than means. Therefore, the Lemly Index is sensitive to brief spikes in contaminant levels, but is unaffected by prevailing contaminant levels. Furthermore, the Lemly Index is strongly dependent on sampling periods and sampling frequency, yet Lemly provided no sampling protocol. For these reasons, there is a need to develop a new protocol and index that replaces Lemly's categorical rating format (low, medium, high) with a direct estimate of the probability of adverse effects (e.g.10%+ probability of reproductive impairment). Despite the weaknesses of the Lemly Index, we continue to use it for comparative purposes as long as it remains the best available overall index of the ecological risk of selenium.

Boron Ecological Risk Guidelines

The dietary and tissue concentrations of boron associated with toxic effects on fish and wildlife are not as well known as for selenium. The effects of dietary exposures and waterborne exposures (without dietary exposures) are known for some taxa (Table 2), but there are as yet no definitive data associating tissue concentrations with adverse effects in fish and invertebrates. Boron concentrations as low as 0.1 mg/l in water may adversely affect reproduction of sensitive fish species (review in NIWQP, 1998).

The role of the California Department of Fish and Game (CDFG) and the USFWS in this interagency program is to implement the biomonitoring portion of the Compliance Monitoring Program. The methods used by the CDFG and USFWS are described in the Quality Assurance Project Plan for Use and Operation of the Grassland Bypass Project (QAPP; Entrix, Inc., 1997). These methods are also based on standard operating procedures described in Standard Operation Procedures

Table 2. Recommended Ecological Risk Guidelines for Boron Concentrations.

Medium	Effects on	Units	No Effect	Level of Concern	Toxicity
Water	fish (catfish and trout embryos)	mg L	< 5	5-25	> 25
Water	invertebrates (*Daphnia*)	mg L	< 6	6-13	> 13
Water	vegetation (crops and aquatic plants)	mg L	< 0.5	0.5-10	> 10
Waterfowl diet	duckling growth	mg kg (dry weight)		> 30	
Waterfowl egg	embryo mortality	mg kg (dry weight)	<1	> 10	>30

Notes

- Water guidelines for invertebrates are based on the "no observed adverse effects level" and "lowest observed adverse effects level" for *Daphnia magna* (Lewis and Valentine 1981, Gersich 1984)
- Waterfowl diet guidelines are based on mallard ducks (Smith and Anders 1989).
- The waterfowl egg no effect level is based on poultry data from Romanoff and Romanoff (1949) and San Joaquin Valley field data for reference sites (R. L. Hothem and D. Welsh, J. P. Skorupa et al.)
- The waterfowl egg level of concern and toxicity threshold are based on Smith and Anders (1989), Stanley et al. (1996), and the "order-of-magitude rule of thumb" (toxicity at about 10 times background concentrations)
- The US Environmental Protection Agency's suggested no adverse response level for drinking water is 0.6 mg/L

for Environmental Contaminant Operations (USFWS, 1995) and standards used by the other agencies participating in the compliance monitoring program. Deviations from the QAPP that have occurred since 1996 will be discussed later in this section.

To obtain baseline data for this Project, the USFWS began sampling in March 1992, after the reuse of the SLD was initially proposed by the USBR in 1991. The CDFG began sampling in August of 1993. USFWS and CDFG sampling plans before the reopening of the SLD and the early drafts of the monitoring plan were mutually influencing. Therefore, methods used by both agencies before the final approval of the QAPP are, except for a few minor differences, identical to the methods ultimately approved by the Data Collection and Reporting Team. The sampling schedule, though, as discussed below, now follows a regular timetable.

Matrices Sampled

Samples of the biota were collected at each site and analyzed for selenium and boron. Aquatic specimens were collected with hand nets, seine nets and by electrofishing. Mosquitofish (*Gambusia affinis*), inland silversides (*Menidia beryllina*), red shiners (*Cyprinella lutrensis*), fathead minnows (*Pimephales promelas*), carp (*Cyprinus carpio*), white catfish (*Ameiurus catus*), and green sunfish (*Lepomis cyanellus*) were the principal species of fish collected. Waterboatmen (family: *Corixidae*), backswimmers (family: *Notonectidae*), and red crayfish (*Procambarus clarkii*) were the principal invertebrates collected. Separation of biological samples from unwanted material also collected in the nets was accomplished by using stainless steel or teflon sieves, and glass (or enamel) pans pre-rinsed with deionized water then native water. To the extent possible, three replicate, composite samples (minimum 5 individuals totaling at least 2 grams for each composite) of each primary species listed above were collected, but other species were also collected. Composite samples of skin-less muscle (fillets) from the larger gamefish species were submitted for analysis; smaller forage fish and medium-size fish species were analyzed as composite whole-body samples except as noted below. Estimates of a conversion factor for relating selenium concentration in skeletal muscle (M) to whole-body concentrations (WB) range from M=0.6 x WB for many freshwater fish (Lemly and Smith, 1987) to M=0.045+1.23 x WB for bluegills and M=-0.39+1.32 x WB for largemouth bass (Saiki et al., 1991).

Between 1992 and 1999, frog tadpoles occasionally collected from Mud Slough and Salt Slough sites were archived. In 1999 these archived samples were analyzed.

Additional samples were collected and analyzed from these sites in 2000.

Analyses of fish samples collected from the San Joaquin River sites and Mud Slough (Sites E, G, and H) were prioritized to first meet the objectives of the Compliance Monitoring Plan (Section 4.5.1.4). Supplemental fish samples were analyzed only when baseline biota target species and sample sizes could not be obtained.

In WY 1999 and 2000 several samples of fish and invertebrates submitted for analysis were of insufficient mass to permit individual measurement of the water content (percent moisture) of the sample, a measurement used to calculate the dry weight selenium concentration in the sample. For these samples (designated with asterisk on the graphs), an average percent moisture was calculated from the percent moisture measurements of comparable samples in the closest possible conditions of sampling location, time, species, and size of organism. This average percent moisture was used to calculate the dry weight selenium concentration. Selenium concentrations discussed in text and displayed in figures below are averages of composite sample concentrations except for bird eggs and except where otherwise stated.

The seed heads of wetland plants that provide food for waterfowl were collected along the sloughs in the late summer of the years 1995-2000. Much of this plant material was archived until analyzed in the year 2001 for this report.

Waterfowl and/or shorebird eggs, depending on availability, were collected from areas adjacent to Mud Slough and the SLD in the spring of 1996, 1997, and 1998. In addition, in 1992 snowy egret and black-crowned night heron eggs were collected at East Big Lake, which has served as a reference sampling site for the USFWS. Bird eggs were analyzed individually, and the results are discussed and displayed below as individual concentrations and geometric means.

Graphs of whole-body and avian egg selenium concentrations presented in this report include indications of the threshold concentrations delimiting the risk ranges listed above (Table 1). The threshold between the no effect zone and the level of concern zone is indicated by a horizontal line of short dashes; the toxicity threshold is marked on each graph by a horizontal line of long dashes.

All biota samples were kept on ice or on dry ice while in the field then kept frozen to 0 C during storage and shipment. For all samples, after freeze drying, homogenization, and nitric-perchloric digestion, total selenium was determined by hydride generation atomic absorption spectrophotometry, and boron was determined by inductively coupled (argon) plasma spectroscopy.

Sampling Sites

Between 1992 and 1999, biological samples have been collected from two sites on Salt Slough, five sites on Mud Slough, two sites in the SLD, two sites on the San Joaquin River, and one reference site that does not receive selenium-contaminated drainwater (East Big Lake). Beginning in 1995, sampling efforts were concentrated on the seven sites identified in the Compliance Monitoring Plan: four sites on Mud Slough (C, D, E, and I), one on Salt Slough (F), and two San Joaquin River sites (G and H; Figure 1). Site C is located upstream of where the Grassland Bypass discharges into Mud Slough. Site D is located immediately downstream of the discharge point. Site I is a small, seasonally flooded backwater area fed by Mud Slough and is located approximately 1 mile downstream from Site D. Site E is located further downstream where Mud Slough crosses State Highway 140. To assess the mitigative effects of drainwater removal from Salt Slough, one sample point, Site F, is located on the San Luis National Wildlife Refuge approximately 2 miles upstream of where State Highway 165 crosses Salt Slough. Site G is located on the San Joaquin River at Fremont Ford, upstream of the Mud Slough confluence, while Site H is located on the San Joaquin River 200 meters upstream of the confluence of the main branch of the Merced River, downstream of the Mud Slough confluence. Sites C, D, F, and I are monitored by the USFWS while CDFG monitors Sites E, G, and H.

Sampling Times

Baseline sampling conducted by the USFWS occurred monthly during the spring and summer of 1992 and then less frequently during 1993 and 1994. Baseline sampling by CDFG occurred during the summer and fall of 1993 and then resumed in the spring of 1996. Between 1992 and 1995 sampling by either the CDFG and the USFWS occurred at least once every season. Experience and interagency discussions led to the identification of four sampling times based on historic water use and drainage practices and on seasonal use of wetland resources by fish and wildlife. Biota sampling since 1995 has been synchronized to occur during the months of November, March, June, and August. Since 1996, avian eggs have been collected in May and June.

Statistical Analysis

Contaminant concentrations in individuals are generally lognormally distributed. Therefore, the geometric mean is a more appropriate measure of central tendency than the

arithmetic mean for such contaminant data. However, much of the contaminant analysis for this project is done on composite samples, which effectively represent average contaminant concentrations in population samples often consisting of 25 or more individuals. Therefore, even though the distribution of concentrations in individuals is not expected to be normal, the distribution of concentration in composite samples is generally expected to approach a normal distribution (Central Limit Theorem). For this reason, the arithmetic mean is appropriate for such composite samples, and arithmetic means are presented in this report except where otherwise specified.

Student's 2-tail t-tests were used to compare means of concentrations for groups of samples collected at different times at the sampling sites (unpaired samples with unequal variances).

Selenium Hazard Assessment

The protocol proposed by Lemly (1995, 1996) was used to estimate the overall hazard of selenium to the ecosystems affected by the GBP. The implementation of the protocol presented here incorporates data for water from Central Valley Regional Water Quality Control Board and data for sediment from the USBR in addition to biological data collected by the USFWS, CDFG, and CH2M HILL. In accordance with Lemly's protocol, the assessments use the highest (rather than the mean) concentrations of selenium found in each of the ecosystem components (Appendix A).

Data from the biological sampling in November 1996, shortly after GBP initiation, were excluded from the WY 1997 hazard assessments because temporarily extremely high concentrations of selenium in some fish may have been due to those fish having been flushed out of the previously stagnant, evapoconcentrated SLD. Very high levels of selenium in the water associated with storm flows were not excluded because elevated concentrations persisted long enough (especially in February 1998) potentially to affect the ecosystem adversely.

Concentrations of selenium in fish eggs were estimated from whole-body concentrations using the conversion factor (fish egg selenium = fish whole-body selenium x 3.3) recommended in Lemly (1995, 1996).

Site E (lower Mud Slough) and the San Joaquin River (SJR) sites (G and H) cannot be rated as to overall hazard of selenium because not all media have been collected in order to assess these sites. Confounding the evaluation further at the SJR sites is the lack of sufficient catch of invertebrates (e.g., no samples for three quarters of WY 1999, and in WY 2000 no samples at Site G in November 1999 and at Site H in November 1999 and August 2000) and the prevalence of introduced fish species with broad environmental tolerances.

Departures from the Compliance Monitoring Plan and Quality Assurance Project Plan

To ensure reliable and consistent data, the USFWS and the CDFG followed the procedures specified in the Compliance Monitoring Plan and the Quality Assurance Project Plan (QAPP) with the exceptions listed below.

External quality assurance samples (QAPP Appendix A, Section 7) were not submitted to analytical labs with GBP biological samples before January of 1998. External quality assurance samples are biological materials (e.g. powdered chicken egg, shark liver) with certified concentrations of the analytes of concern (selenium, boron), supplied by third party laboratories. The analyte concentrations in these samples are known to the agencies submitting the samples, but not known to the laboratory doing the analysis. This blind test of laboratory analytical precision supplements the internal quality control procedures of the analytical laboratory. Internal quality control protocols specified in the QAPP (procedural blanks, duplicate samples, and spiked samples) have been followed throughout the history of GBP biological sampling.

The USFWS used stainless steel (rather than Teflon) strainers for sorting small fish (QAPP Appendix A, Section 4.7).

For some species at some locations it has not been practical at some times to collect the full target minimum numbers of individuals and/or mass per sample that are specified in the Compliance Monitoring Plan (Section 4.5.1.4) and the QAPP (Appendix A, Section 4.5). Actual masses and numbers of individuals per sample are shown in the appendix to this chapter.

From 1992 through 1997 all biological samples collected by the USFWS (except bird eggs in 1996 and 1997) were analyzed by Environmental Trace Laboratory at the University of Missouri in accordance with the QAPP (Appendix A, Section 6.1). Bird egg samples collected in 1996 and 1997 were analyzed at Trace Element Research Laboratory (TERL) at Texas A & M University, a USFWS contract laboratory. All biological samples collected in 1998 were analyzed at TERL. TERL is subject to the same performance standards as Environmental Trace Substance Laboratory, therefore, the GBP quality assurance objectives (QAPP Table 1) apply to analytical results from TERL. In 1999 all biological samples were analyzed at the Water Pollution Control

Laboratory of the CDFG in Rancho Cordova, California, after this laboratory was screened and approved by the GBP Quality Control Officer.

Seine net mesh size was increased from 3/16 inch to 1/4 inch after the first two pre-Project collections in 1993 from sampling Sites E, G, and H (QAPP Appendix A, Section 4.6). This change in sampling gear resulted in significant declines in catch abundance of smaller forage fish without altering diversity of representative assemblages. Data collected from 1993 sampling efforts at these sites were not included in making quantitative spatial or temporal comparisons between sites unless otherwise noted. At Sites C, D, I, and F, 1/8 inch mesh seines were used from 1992 through 1998. Since 1999 a 3/16 inch mesh bag seine has been used at these sites in place of the 1/8 inch mesh bag seine that was previously used by the USFWS.

Results

Salt Slough (Site F)

Fish (Whole-Body)

Salt Slough is a principal wetland water supply channel from which drainwater has been removed by the GBP. Concentrations of selenium in Salt Slough fish composite samples declined during the first year of operation of the GBP but have stabilized since then at levels well below the level of concern threshold (Figures 2 and 3), with the exception of March 1998, when concentrations rose in the aftermath of storms that resulted in substantial releases of drainwater into Salt Slough. The average of all composite samples of fish at this site in WY 2000 was 2.6 mg/kg (n=66), substantially below the warmwater fish level of concern threshold (4 mg/kg), significantly below the pre-Project average (6.7 mg/kg, n=78; p<0.000001), but not significantly different from the average for the previous year (2.3 mg/kg, n=46; p=0.2).

Tadpoles

Frog tadpoles (mainly bullfrog, *Rana catesbeiana*) have been collected only occasionally in the GBP area. Results suggest that in Salt Slough, selenium concentrations in tadpoles, as in fish and invertebrates, declined after implementation of the GBP (Figure 4). A composite sample of four bullfrog tadpoles collected in Salt Slough in August 1999 had about half the selenium concentration (2.6 mg/kg) of a single bullfrog tadpole collected in March 1993 (5.8 mg/kg). However, the selenium concentration was higher in a composite sample of three bullfrog tadpoles in June 2000 (2.9 mg/kg), and were still higher on average in August 2000 (7.5 mg/kg in a composite sample of three tadpoles; 2.3 mg/kg in a single, 19 g frog).

Invertebrates

During WY 2000, selenium concentrations in invertebrates collected from Salt Slough (Figure 5) remained within the range of concentrations associated with no known adverse effects (<3 mg/kg) on animals that eat invertebrates. Invertebrates (only red crayfish) were collected in sufficient numbers to analyze only in March (2 composite samples of six individuals each) and August (three composite samples of three large, five medium-sized, and nine small individuals) of 2000. The mean concentration of selenium in all invertebrate samples collected in WY 2000 (2.1 mg/kg, n=5) was significantly below (p<0.00001) the pre-Project mean (4.3 mg/kg, n=26), but not significantly different (p=0.63) from the WY 1999 mean (2.3 mg/kg, n=10).

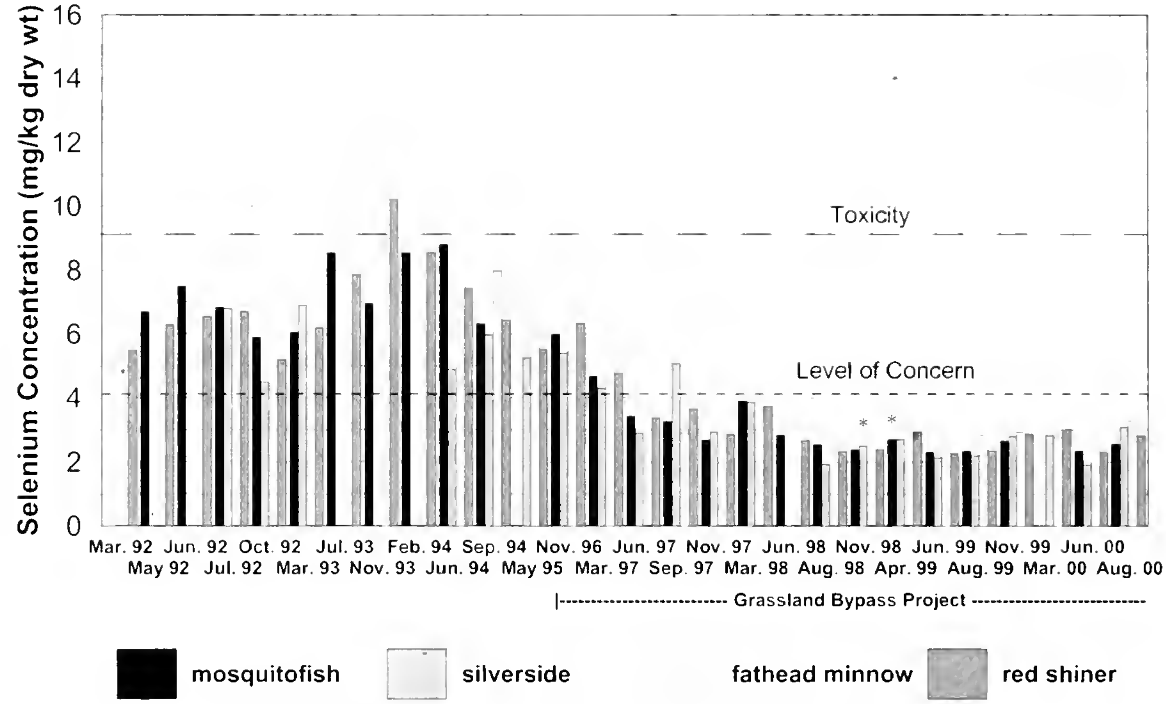
Mud Slough 0.4 km above SLD Outfall (Site C)

Fish (Whole-Body)

During the fourth year of operation of the GBP, selenium concentrations in fish just above the SLD outfall rose somewhat compared to the previous year (Figures 6 and 7). Average selenium concentration in all fish sampled at Site C during WY 2000 (3.0 mg/kg, whole body dry weight, n=65) was significantly higher (p=0.013) than the average for the previous year (2.6 mg/kg, n=52), but was not significantly different (p=0.16) from the pre-Project average at Site C (2.7 mg/kg, n=38). The warmwater fish level of concern threshold (4 mg/kg; see Table 1) was slightly exceeded by the average selenium concentrations in composite samples of fathead minnows in November 1999 (4.3 mg/kg, one composite sample of three individuals) and March 2000 (4.2 mg/kg, three composite samples of eight, thirteen, and eight fish), and by the average selenium concentration (4.1 mg/kg) of two composite samples of mosquitofish in March 2000 (3.3 mg/kg in 22 females, and 4.9 mg/kg in eight males); otherwise, average selenium concentrations in all fish sampled at Site C remained at no-effect levels during the remainder of WY 2000.

In June 2000 at this site two bigscale logperch (*Percina macrolepida*) were collected (selenium: 2.8 mg/kg), the first of the perch family to be sampled at this site since the current biological monitoring program began in

Figure 2. Selenium in Small Fish in Salt Slough (Site F). Each Bar Represents an Average of Composite Samples



* Calculated from wet wt concentration using average percent moisture of similar samples

Figure 3. Selenium in Medium-Size Fish in Salt Slough (Site F)

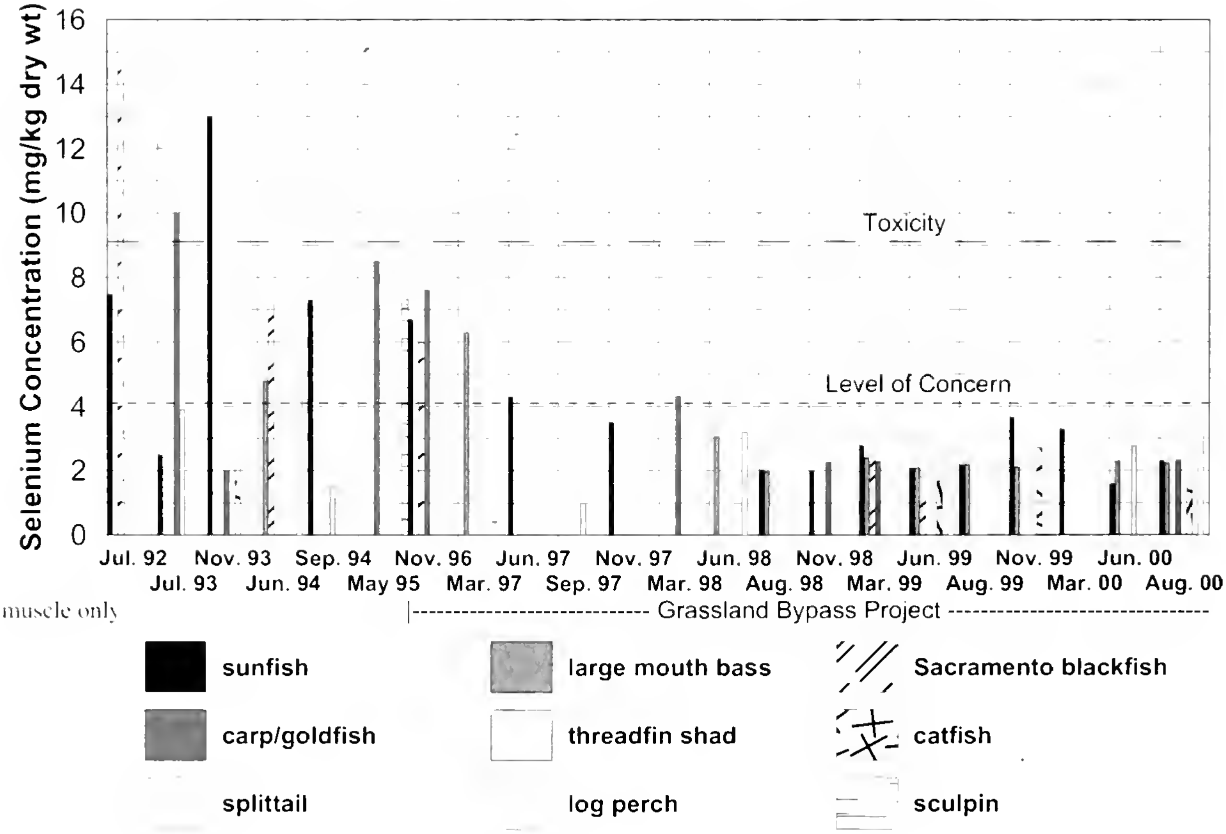


Figure 4. Selenium in Bullfrogs/Tadpoles in Salt Slough (Site F)

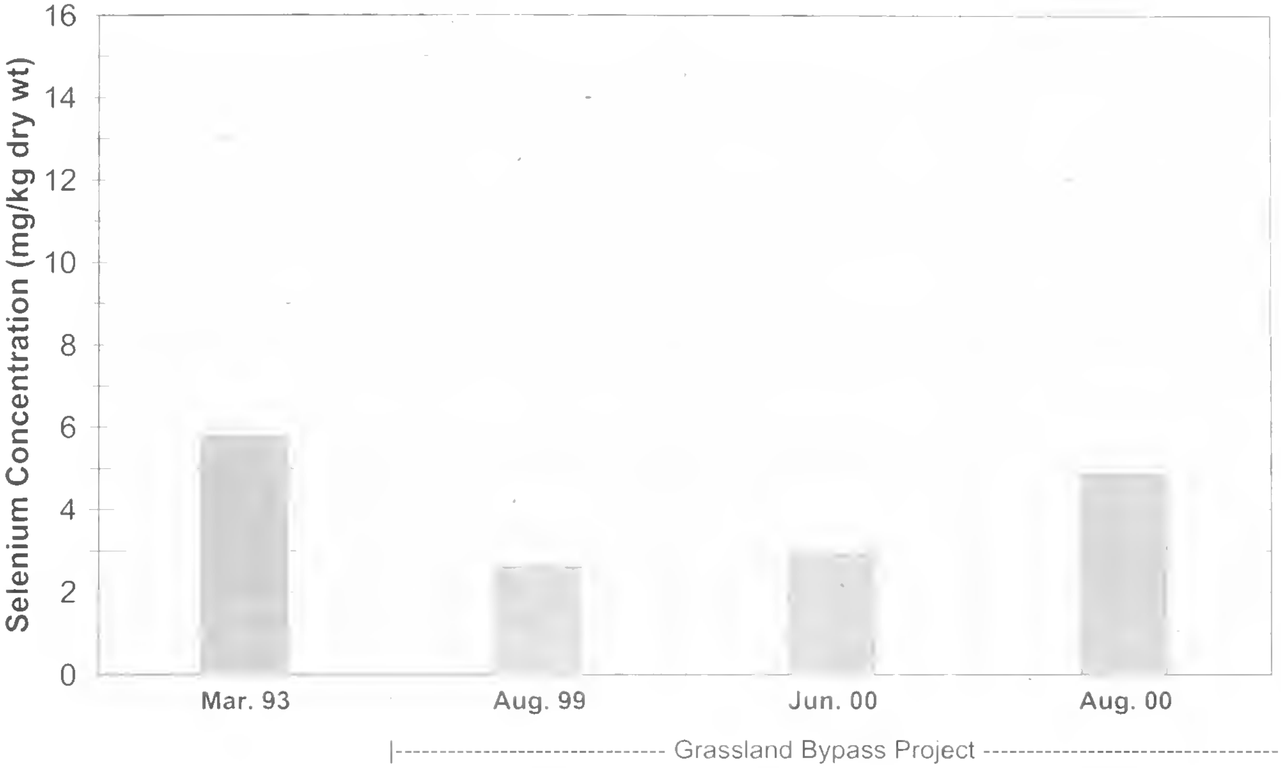
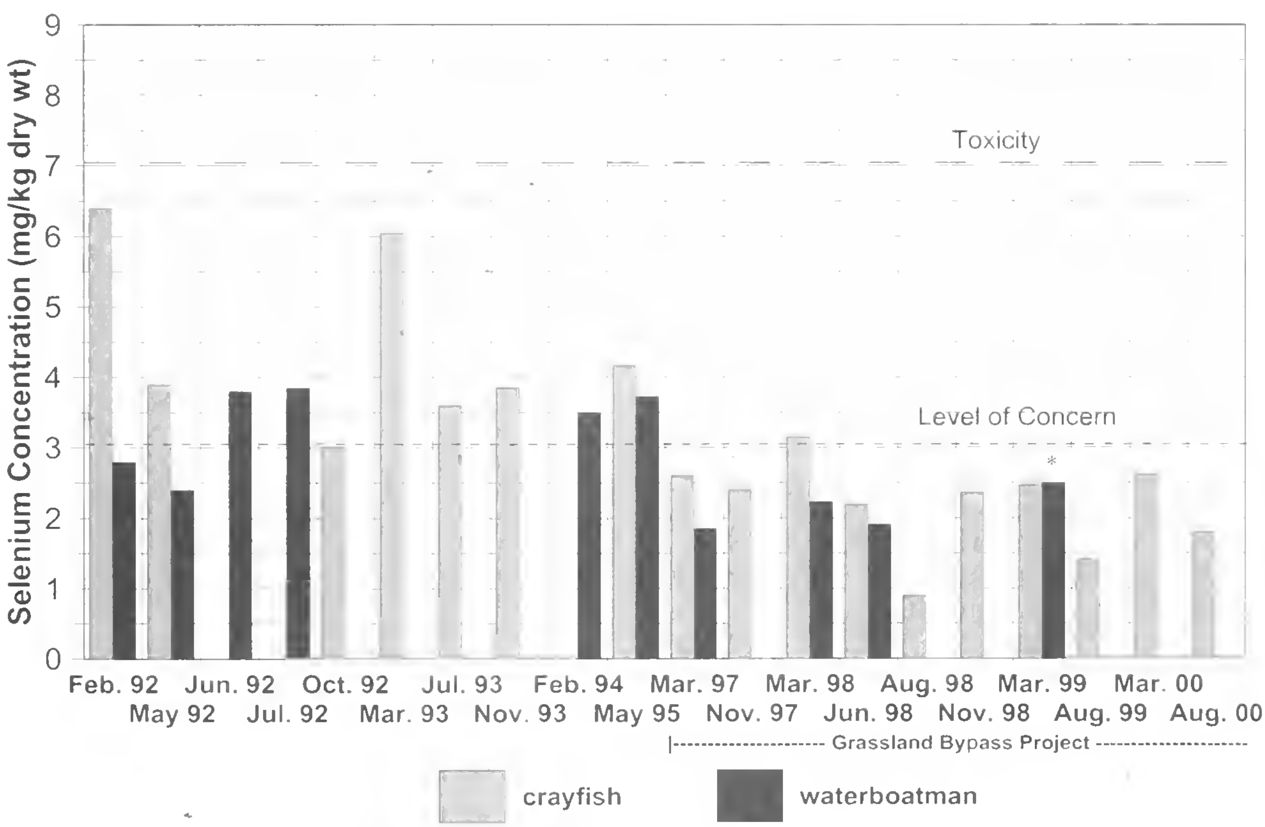
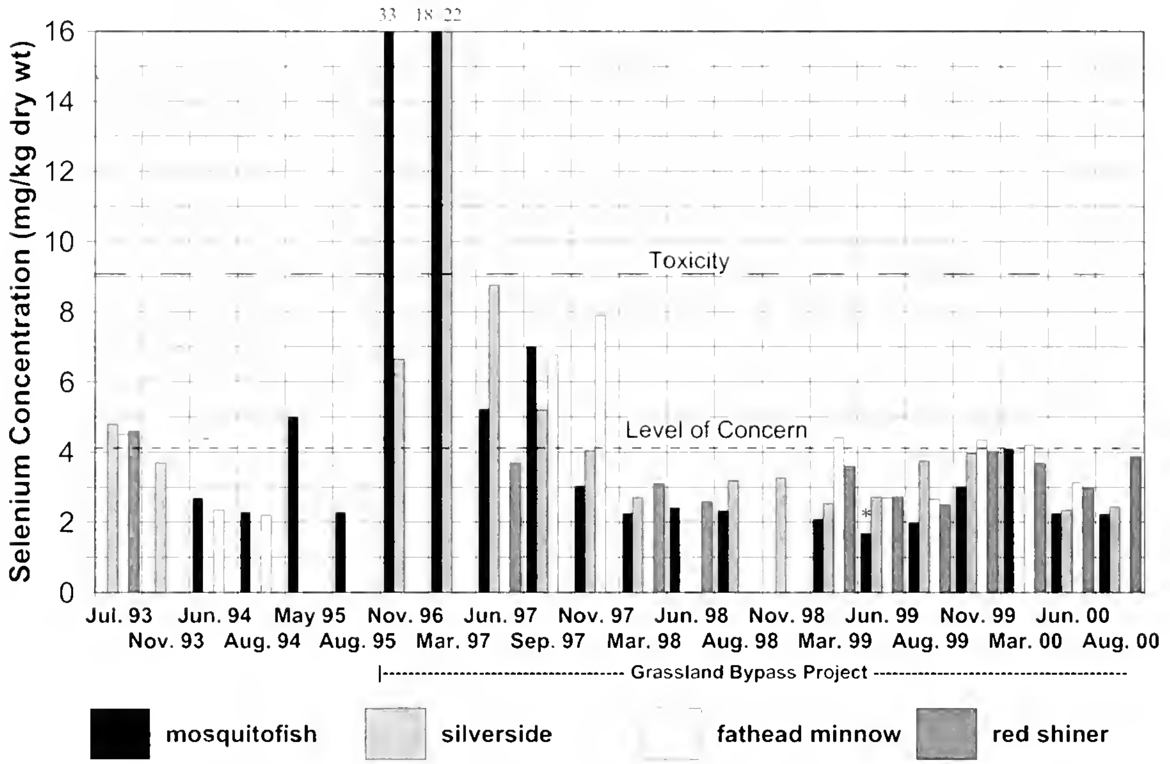


Figure 5. Selenium in Invertebrates in Salt Slough (Site F)



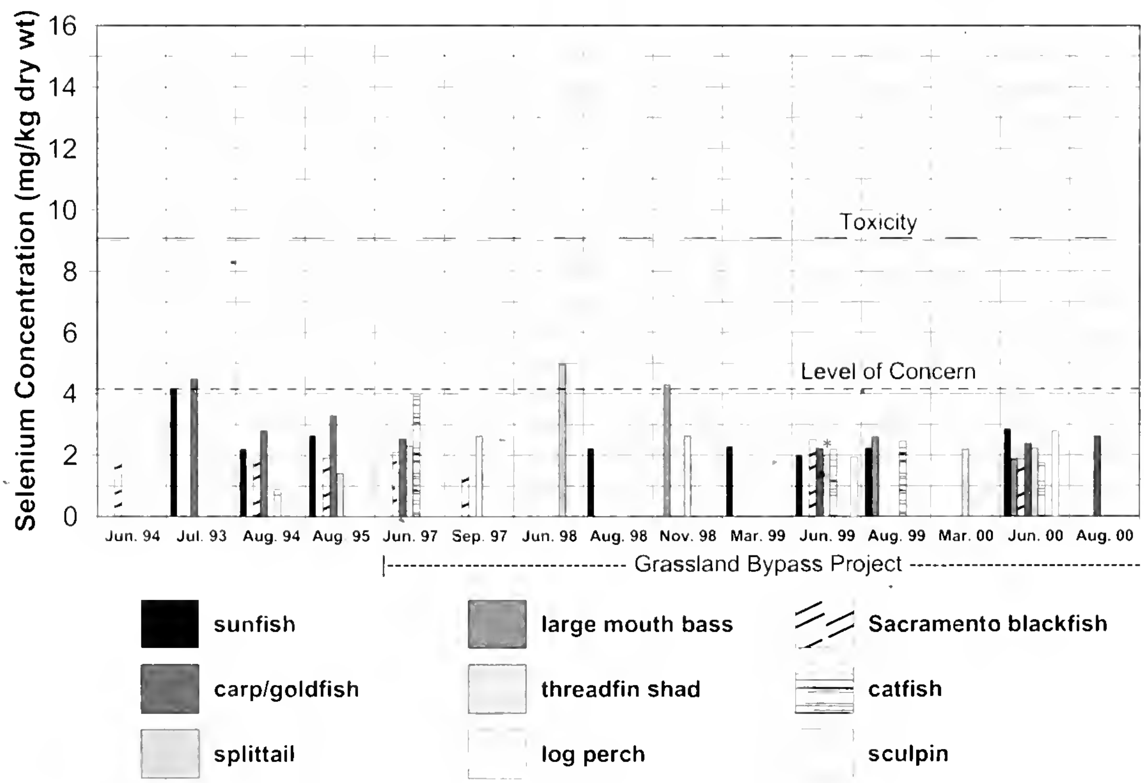
* Calculated from wet wt concentration using average percent moisture of similar samples

Figure 6. Selenium in Small Fish in Mud Slough above the San Luis Drain Discharge (Site C)



* Calculated from wet wt concentration using average percent moisture of similar samples

Figure 7. Selenium in Medium-Size Fish in Mud Slough above the San Luis Drain Discharge (Site C)



* Calculated from wet wt concentration using average percent moisture of similar samples

1992. Logperch are bottom-feeders first introduced to California in the 1950's (McGinnis 1984).

Tadpoles

At Site C, a single composite sample of 14 bullfrog tadpoles was collected in June 2000 (Figure 8). The selenium concentration in this sample (2.7 mg/kg) was near the low end of the range of selenium concentrations in four composite samples collected at this site in March, June, and August of the previous year (2.5-4.9 mg/kg). No tadpoles were collected at this site prior to WY 1999.

Invertebrates

In the fourth year of operation of the GBP, selenium concentrations in invertebrates at Site C remained generally about the same as in previous years, below the level of concern threshold (Figure 9). The average concentration in all invertebrate composite samples in WY 2000 was 1.7 mg/kg (n=10), not significantly different (p=0.21) from the previous year (2.1 mg/kg, n=10). However, invertebrates were not collected at this site in sufficient numbers to analyze in August of 2000, the month when the highest average invertebrate selenium concentration (4.3 mg/kg) was measured during the previous year.

Mud Slough 0.2 km below SLD Outfall (Site D)

Fish (Whole-Body)

At Site D, about 200 m below the SLD outfall, average selenium concentrations in fish for the most part remained at levels of concern (4–9 mg/kg dry weight; Figures 10 and 11). The mean of composite selenium concentrations for all fish samples from Site D in the fourth year of the GBP (5.0 mg/kg, n=39) was significantly higher (p=0.005) than the pre-Project mean (3.8 mg/kg, n=68) but not significantly different (p=0.34) from the previous year (5.4 mg/kg, n=43). As in the previous year, within WY 2000, selenium concentrations in fish rose significantly (p=0.005; November 1999-March 2000 average: 4.0 mg/kg, n=14; June-August 2000 average: 5.5 mg/kg, n=25).

Tadpoles

Frog tadpoles have been collected only occasionally at Site D (Figure 12). Selenium concentrations in the two individual samples collected in WY 2000 (4.2 mg/kg, n=1 in March; 4.9, n=1 in June) fell within the range of the two samples previously collected (4.3 mg/kg in a single individual in March 1993 and 8.5 mg/kg in a composite of two individuals in November1996).

Invertebrates

Invertebrates were scarce below the SLD outfall during the fourth year of operation of the GBP as in previous years. In WY 2000, the only invertebrate samples collected here that provided sufficient mass for analysis were a sample of seven damselfly nymphs (2.3 mg/kg) and a 1-gram sample of waterboatmen (2.1 mg/kg), collected in November (Figure 13). Both samples were below the level of concern threshold for effects on animals that eat invertebrates (3 mg/kg).

Mud Slough 1.5 km below SLD Outfall (Site I)

Fish (Whole-Body)

Site I is located along Mud Slough about 1.5 km downstream of the SLD outfall where high winter and spring flows in Mud Slough often overtop the slough channel to form a broad, shallow backwater on the east side of the slough. In the early years of monitoring for the GBP, biological monitoring was done at Site I only when this backwater condition coincided with regular monitoring times for the other sites. Therefore, this site was only monitored occasionally. However, this site represents a better measure of the effects of the GBP on Mud Slough biota because it is further from the diluting influence of aquatic organisms swimming downstream from the cleaner reach of Mud Slough above the outfall of the San Luis Drain. Therefore, since 1999, monitoring at this site has been increased to four times per year, matching the monitoring at the other biological monitoring sites for this project. In the winters of 1998-1999 and 1999-2000 an extensive shallow backwater also formed on the west side of Mud Slough as well as the east side at this location. This additional backwater remained flooded through the summer of both years, and during these years, the third and fourth years of the GBP, fish and invertebrate samples were collected from the main channel at Site I as well as from the backwaters on both sides of the main channel.

At this site during WY 2000, selenium concentrations in fish rose in the summer months compared to the summer months of the previous year (Figures 14 and 15). The mean of composite selenium concentrations for all fish from Site I in August 2000 (10.3 mg/kg, n=14) was

Figure 8. Selenium in Tadpoles in Mud Slough above the San Luis Drain Discharge (Site C)

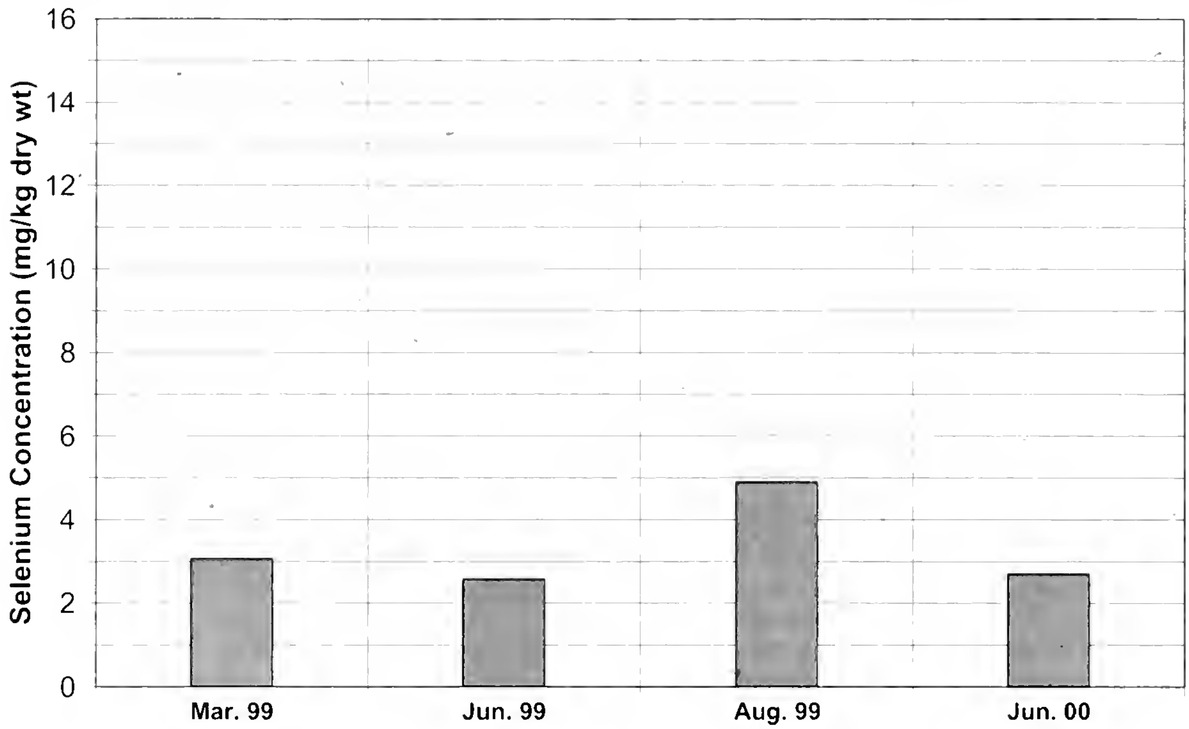
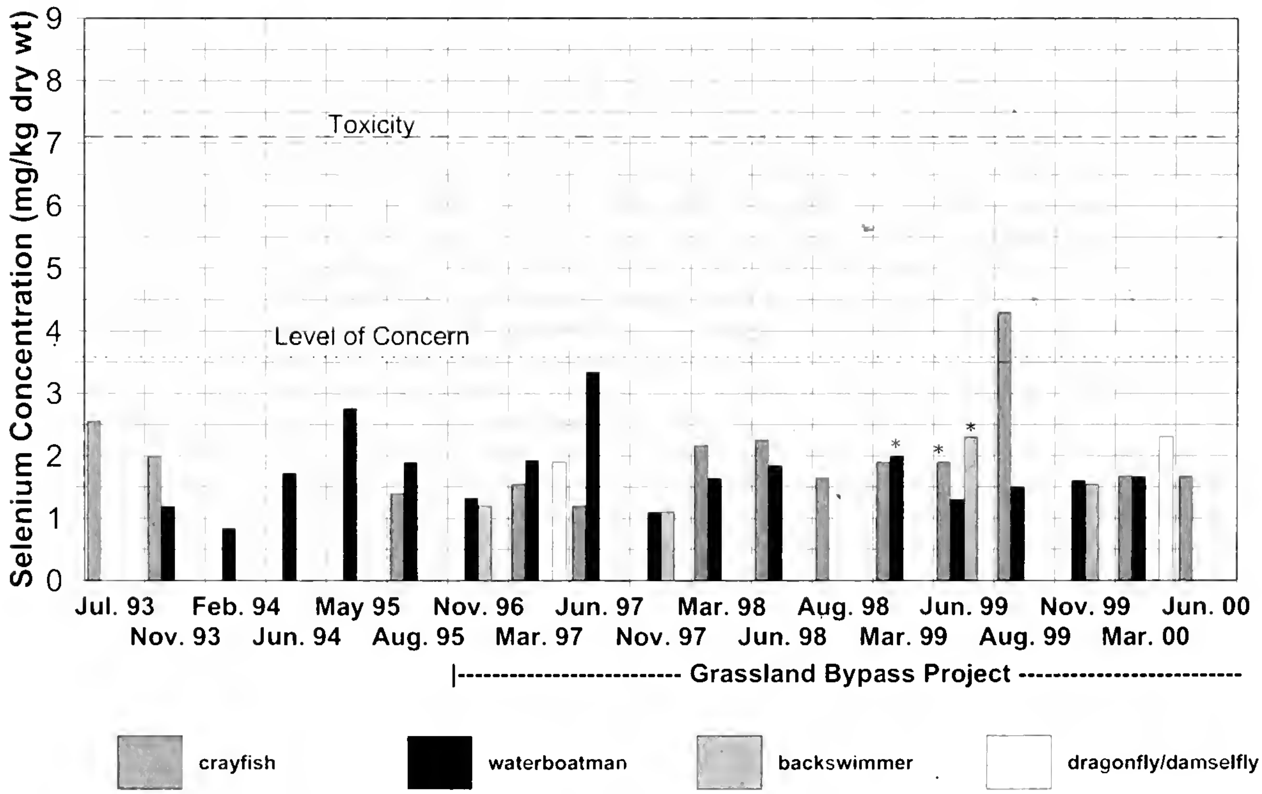
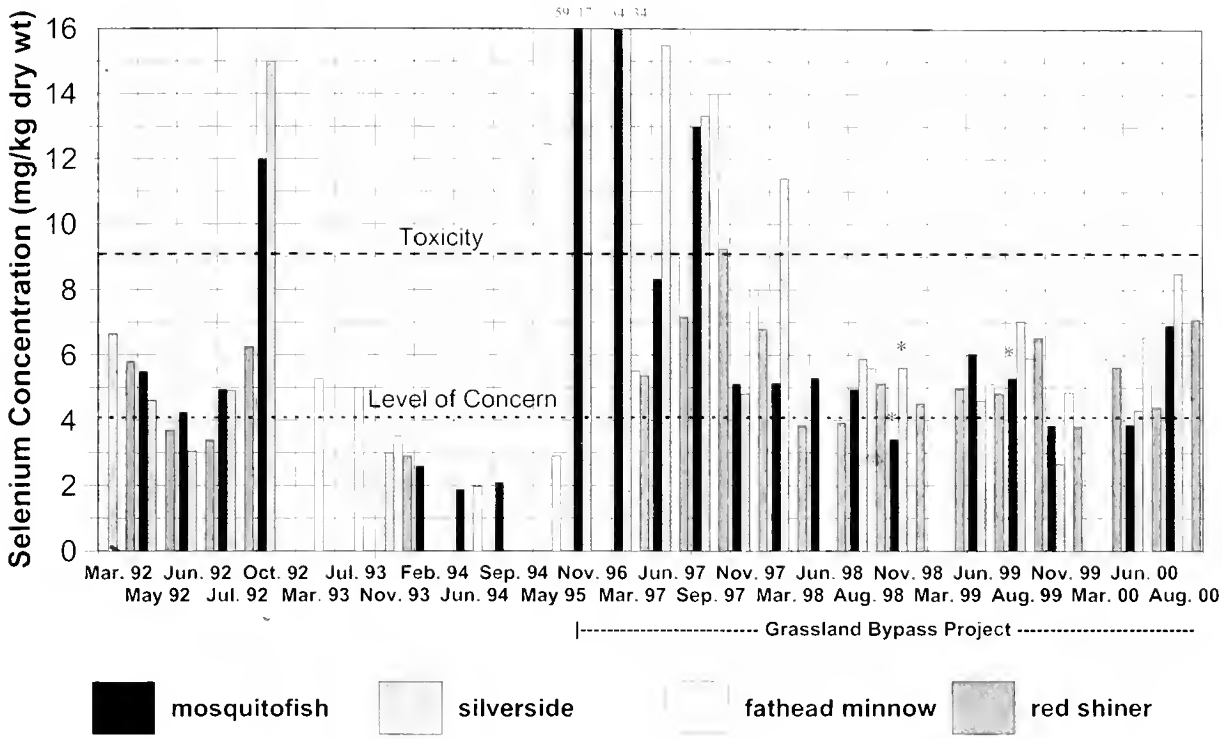


Figure 9. Selenium in Invertebrates in Mud Slough above the San Luis Drain Discharge (Site C)



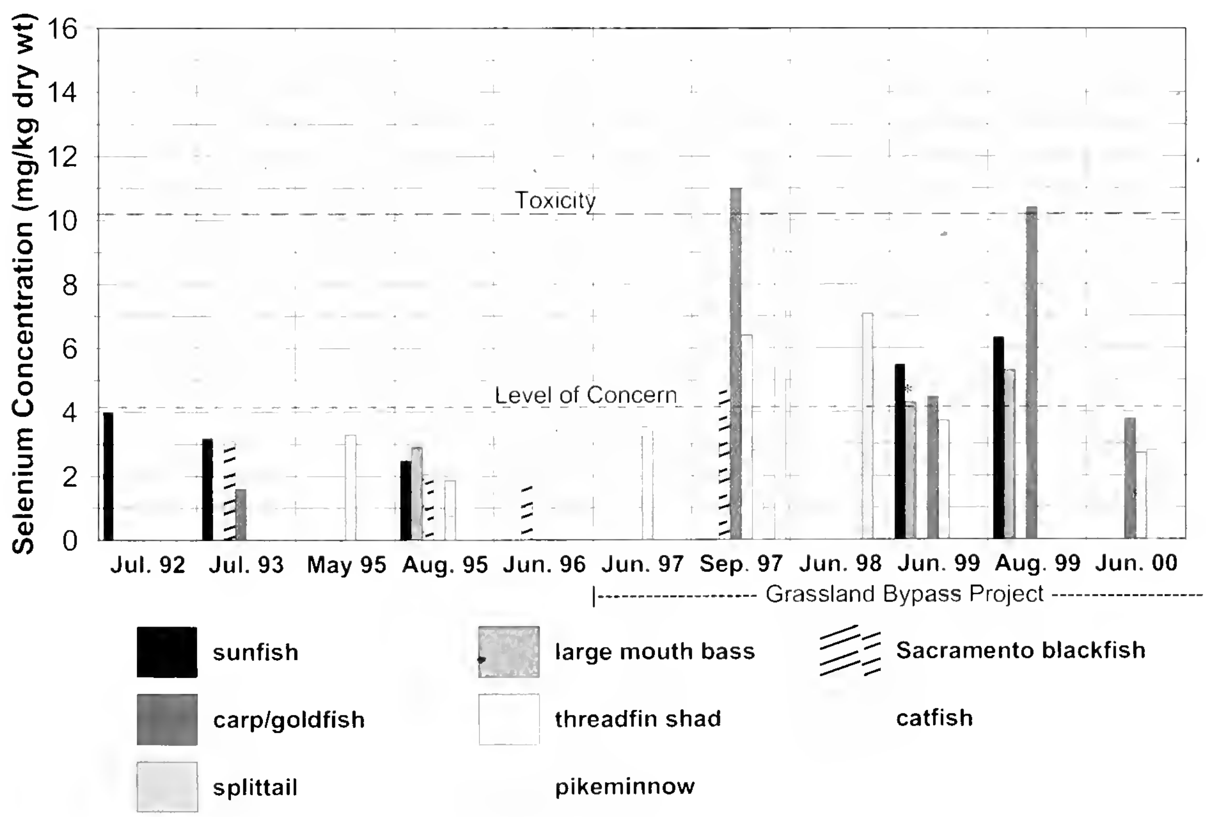
* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 10. Selenium in Small Fish in Mud Slough below the San Luis Drain Discharge (Site D)



* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 11. Selenium in Medium-Size Fish in Mud Slough below the San Luis Drain Discharge (Site D)



* Calculated from wet wt concentration using average percent moisture

Figure 12. Selenium in Tadpoles in Mud Slough below the San Luis Drain Discharge (Site D)

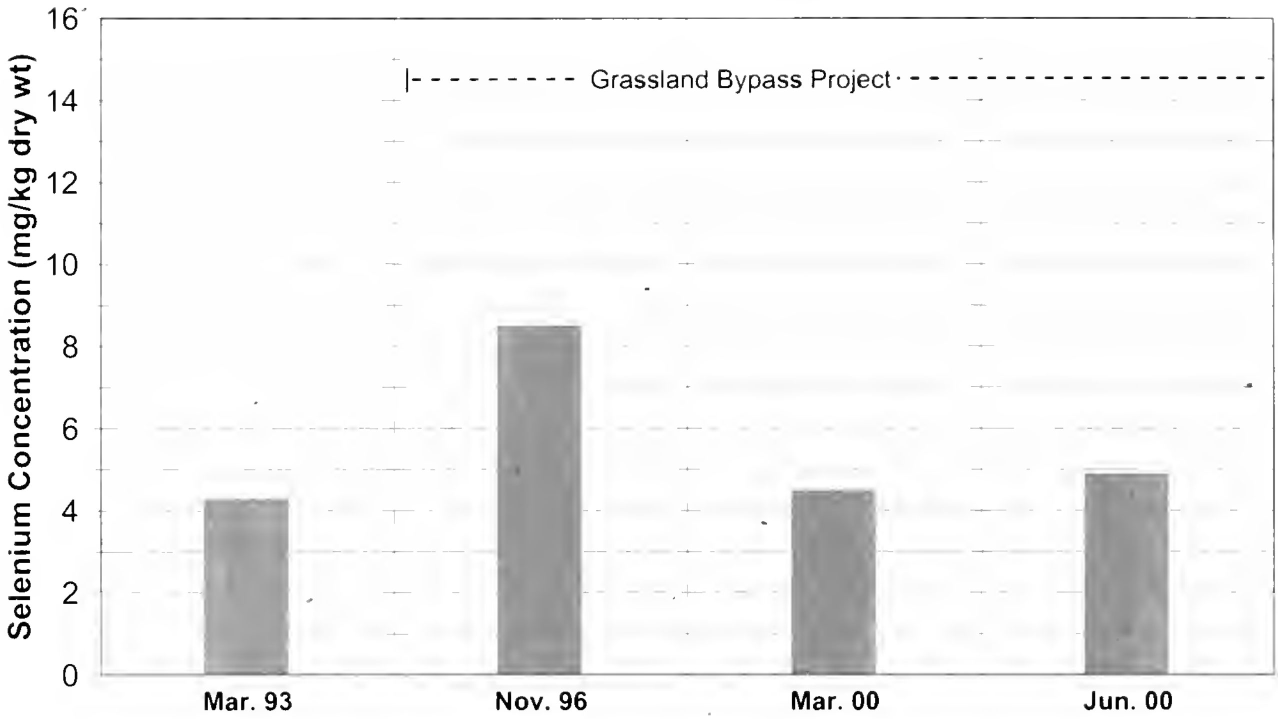
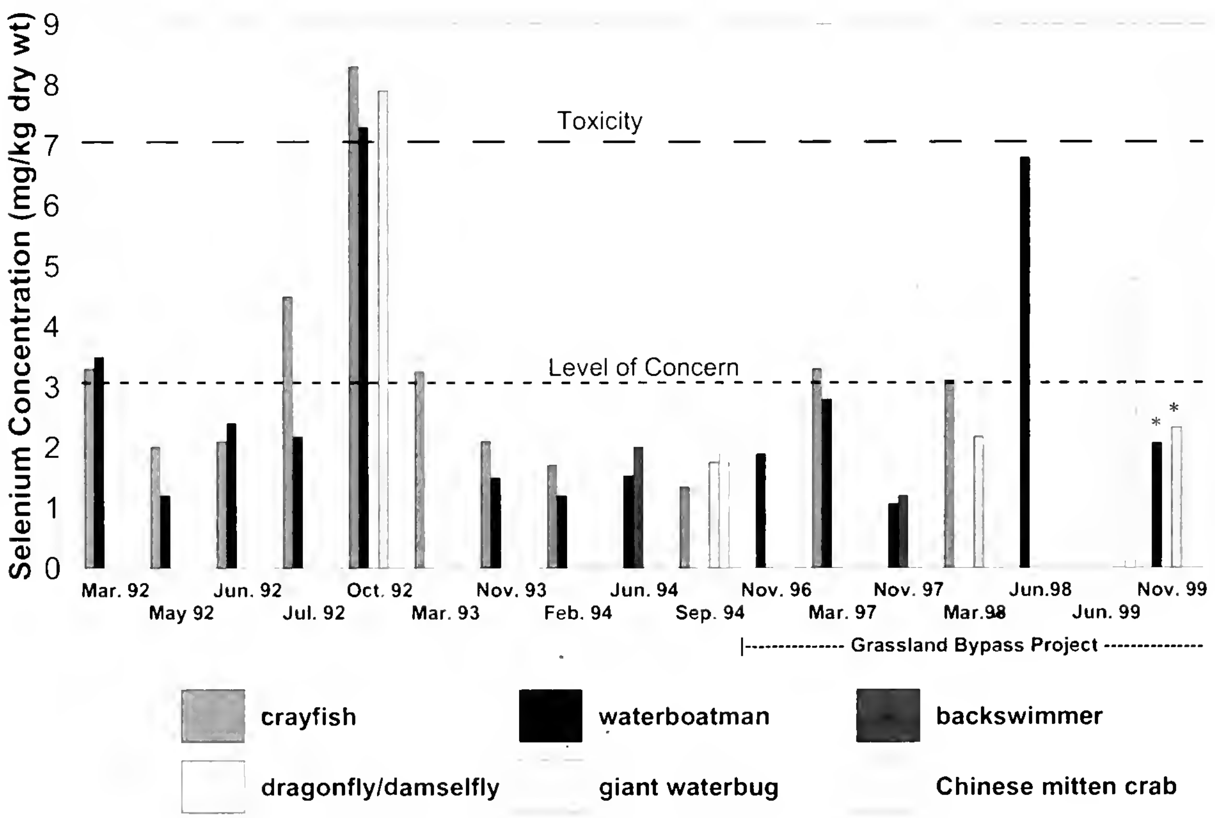


Figure 13. Selenium in Invertebrates in Mud Slough below the San Luis Drain Discharge (Site D)



* Calculated from wet wt concentration using average percent moisture of similar samples

significantly higher (p=0.002) than in August of the previous year (8.3 mg/kg, n=18). Similarly, the mean in June/July was significantly higher (p=0.004) in 2000 (6.2 mg/kg, n=17) than in 1999 (4.8 mg/kg, n=11). Cyclic seasonal variation was sufficiently great to obscure the significance of the overall rise in the yearly average concentration in all fish sampled. The average in WY 2000 (6.7 mg/kg, n=47) was not significantly different (p=0.45) from the average in WY 1999 (6.2 mg/kg, n=39). At this site in August 2000, the mean concentration of composite samples of silversides (12.6 mg/kg, n=3), mosquitofish (10.2 mg/kg, n=6), carp (10.0 mg/kg, n=1), and red shiners (9.1 mg/kg, n=3) all exceeded the toxicity threshold for warmwater fish (9 mg/kg).

Significantly greater bioaccumulation of selenium appears to occur at Site I compared to Site D (in August 2000, mean of all fish at Site I: 10.3 mg/kg, n=14; at Site D: 7.4 mg/kg, n=10, p<0.00001). This may in part be a real effect due to the backwater conditions that frequently occur at Site I. However, it is likely that a principal reason is that composite samples of fish and invertebrates collected at Site D include substantial numbers of individuals that have moved downstream from the cleaner reach of Mud Slough above the outfall of the SLD, thereby diluting the measurements of the effects of drainwater on the biota at Site D.

Tadpoles

Tadpoles have not been collected at this site.

Invertebrates

Average selenium concentration in all invertebrates collected at this site during the fourth year of operation of the GBP was not significantly different (p=0.25) from that of the previous year (WY 2000 average: 5.6 mg/kg, n=7; WY 1999 average: 3.2 mg/kg, n=12). However, as with fish at this site, cyclic seasonal variation evidently obscured the significance of an increase in selenium concentrations that is more evident if the data are stratified by species and sample month (Figure 16). A single red crayfish collected in August 2000 had a selenium concentration of 15.3 mg/kg, more than twice the toxicity threshold for invertebrates as diet (7 mg/kg) and more than twice the concentration of selenium in a composite of three red crayfish (7.1 mg/kg) collected in August 1999.

Figure 14. Selenium in Small Fish in the Mud Slough Backwater below the Drain Discharge (Site I)

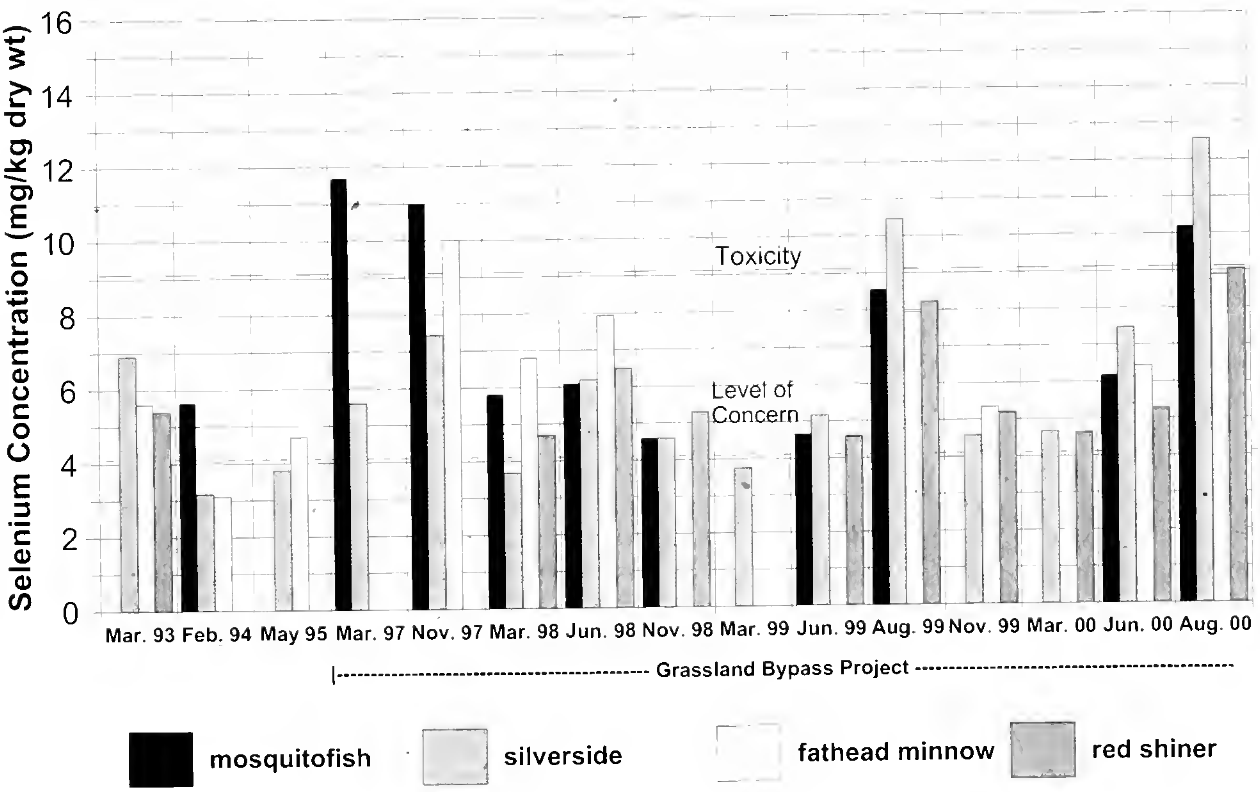
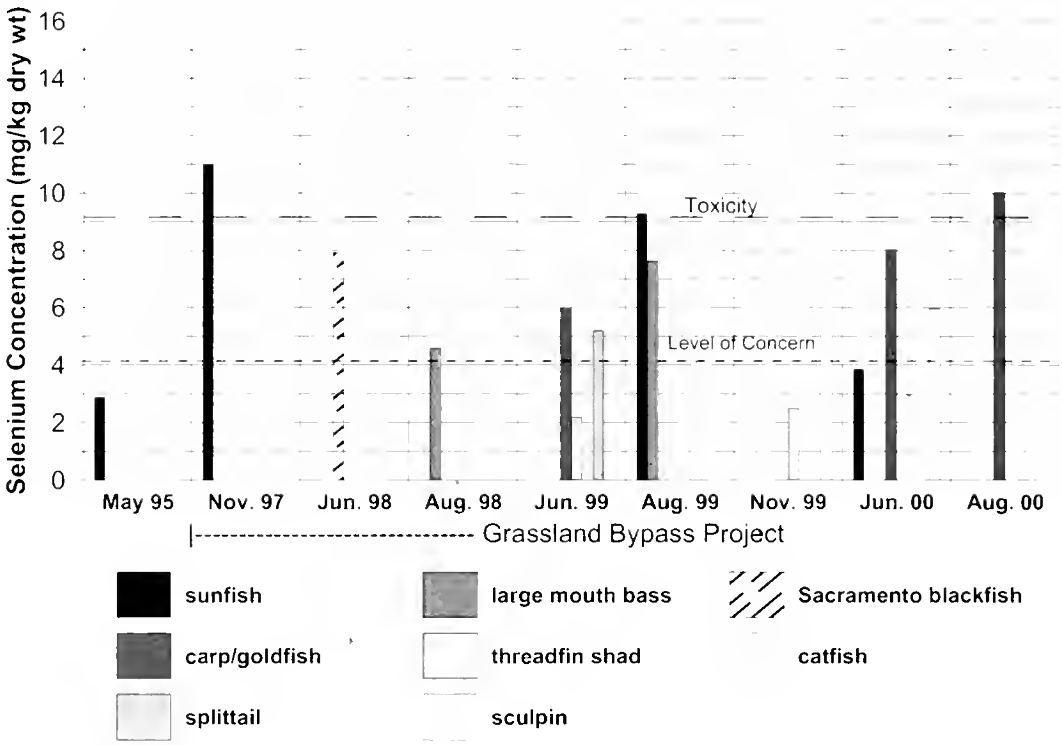


Figure 15. Selenium in Medium-Size Fish in Mud Slough below the Drain Discharge (Site I)



Mud Slough at Highway 140 (Site E)

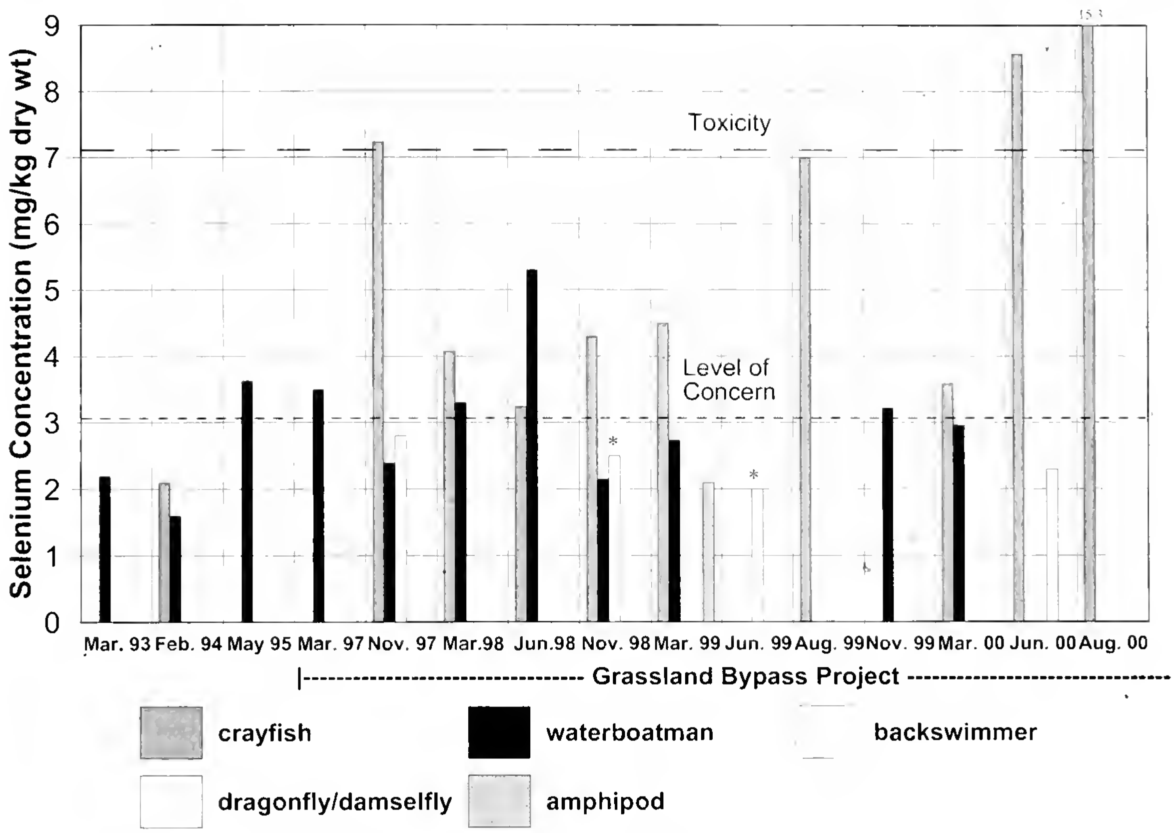
Fish (Whole-Body)

Site E is located in lower Mud Slough between Site D on Mud Slough (just downstream from the discharge point) and the San Joaquin River. This site represents the conditions existing within the system before discharge to the San Joaquin River, and is a site expected to realize some adverse ecosystem impact as a result of Project operations. Average selenium concentrations in all fish collected during WY 2000 ranged from 2.83 to 8.74 mg/kg (Figure 17), remaining either below or within the level of concern (4–9 mg/kg whole-body). Selenium concentrations in fish collected during all four years since Project operations began have generally remained at levels of concern (4–9 mg/kg whole-body), with the exception of fish collected in September 1997 (9.63 mg/kg) and August 1999 (9.21 mg/kg), when toxicity thresholds were exceeded. Compared to concentrations in all fish during the first year of Project operations (WY 1997 μ=8.20 mg/kg, n=9), there has been a significant decrease in selenium concentrations in fish collected during WY 2000 (μ=5.61 mg/kg, n=16, p=0.002), and both other years (WY 1999 μ=6.32 mg/kg, n=10, P=.044; WY 1998 μ=5.65 mg/kg, n=6, p=0.010) since the first year. Despite this, WY 2000 selenium concentrations (μ=5.61 mg/kg) in fish from this site remain significantly elevated (P<0.001) above the average pre-Project concentration of 2.48 mg/kg.

Invertebrates

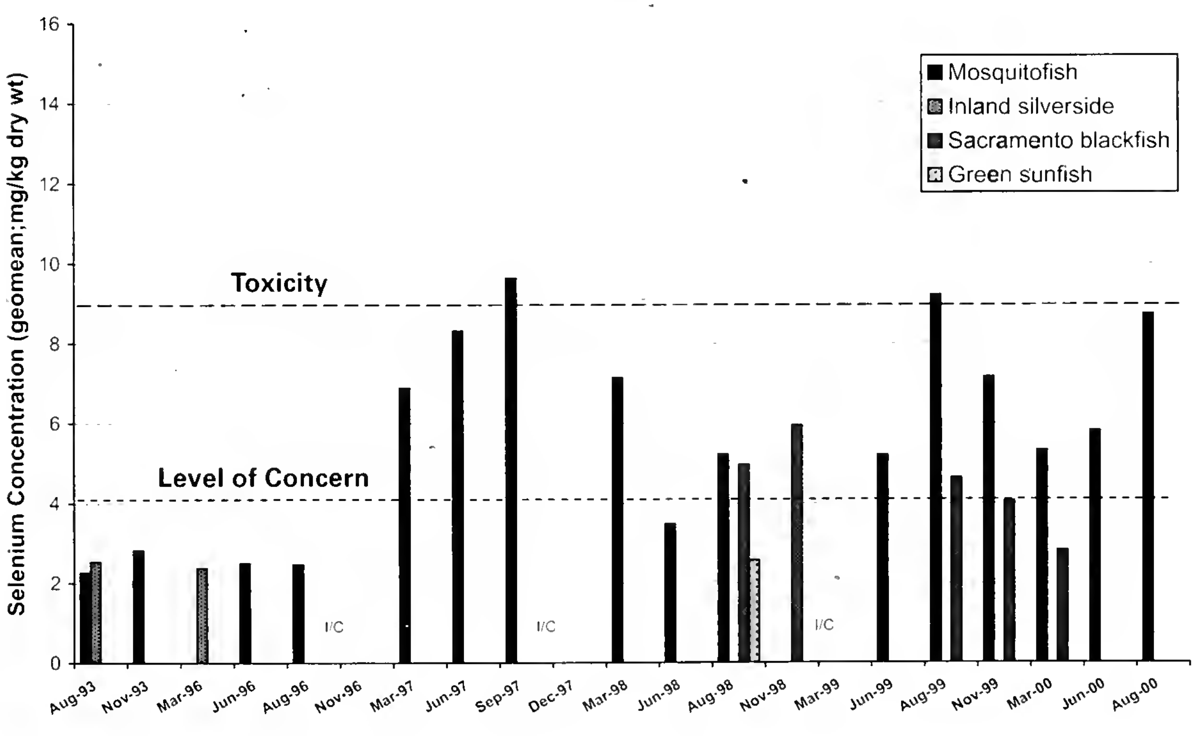
Similar to WY 1999, crayfish were difficult to catch at this site during WY 2000. Similarly, crayfish catch abundance from Sites G and H has been generally low and inconsistent since June 1996 compared to all additional pre-Project capture rates and additional field records dating back to spring of 1992 for another CDFG project. Altering gear types and sampling methods in late WY 1997 did not result in increased capture success. Inconsistent capture rates at Project sites not expected to be adversely impacted by Project operations restricts the speculation that regional crayfish abundance is primarily being influenced by Project operations. One confounding influence that was suspected in some part to be affecting catch rate was local interspecies competition with the introduced Chinese mitten crab, first documented in low numbers within the lower San Joaquin River in 1996, and then in significant numbers in 1998 at all Project sites within upper River and Mud Slough reaches. However since late 1999, mitten crab numbers documented within the lower San Joaquin River have decreased significantly from the population explosion seen in 1998.

Figure 16. Selenium in Invertebrates in the Mud Slough Backwater below the Drain Discharge (Site I)



* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 17. Selenium Concentrations in Whole-Body Fish Tissue from Mud Slough at Hwy 140 (Site E)



I/C Insufficient Catch of Targeted Fish Species for Adequate Sample

Crayfish that were collected at this site during WY 2000 had an average selenium concentration of 3.01 mg/kg (n=3), moving into the threshold of concern level (3 mg/kg; Figure 18) for invertebrates. Crayfish from this site have not exhibited selenium levels above 3 mg/kg since the spring of 1998. Waterboatmen collected from this site during WY 2000 were below the threshold of concern level (3 mg/kg), with an average selenium concentration of 1.66 mg/kg (Figure 18). Annual samples of waterboatmen have consistently remained below the threshold of concern level for all water years since Project operations began.

San Joaquin River at Fremont Ford (Site G)

Fish (Whole-Body)

Site G is located is located at Fremont Ford on the San Joaquin River upstream of the Mud Slough confluence. This site represents the reach of the San Joaquin River that has been largely precluded from receiving Grassland area subsurface drainage water as a result of the GBP. Similar to the first three years of GBP operation, selenium concentrations in fish collected from Site G on the San Joaquin River in WY 2000 continued to reflect removal of local inputs of selenium-laden drainage water. Selenium concentrations in all fish collected during WY 2000 ranged from 1.34 to 2.18 mg/kg (Figure 19), remaining below the level of concern threshold (4 mg/kg whole-body). Average selenium concentration for all fish collected in WY 2000 (μ=1.58, n=16) was not significantly different (p=0.22) from that in the previous year (WY 1999, μ=1.44, n=7). WY 2000 selenium concentrations in fish have decreased significantly from pre-Project levels, which were highest in 1993, ranging from 6.77 to 8.65 mg/kg, consistently within the level of concern range (4–9 mg/kg).

Invertebrates

As expected, selenium concentrations in all invertebrates from this site have continued to decrease since Project operations began. Crayfish that were collected during WY 2000 had average selenium concentration ranging from 0.35 to 0.45 mg/kg (Figure 20), remaining below the threshold of concern level (3 mg/kg) for invertebrates as prey items.

Similar to crayfish, waterboatmen collected from this site during WY 2000 were below the threshold of concern level (3 mg/kg) with an average selenium concentration of 0.55 mg/kg (Figure 20); this level was significantly lower (p=0.026) than waterboatmen collected in WY 1999 (μ=1.16). Annual samples of waterboatmen have consistently remained below the ecological risk level for all water years since Project operations began.

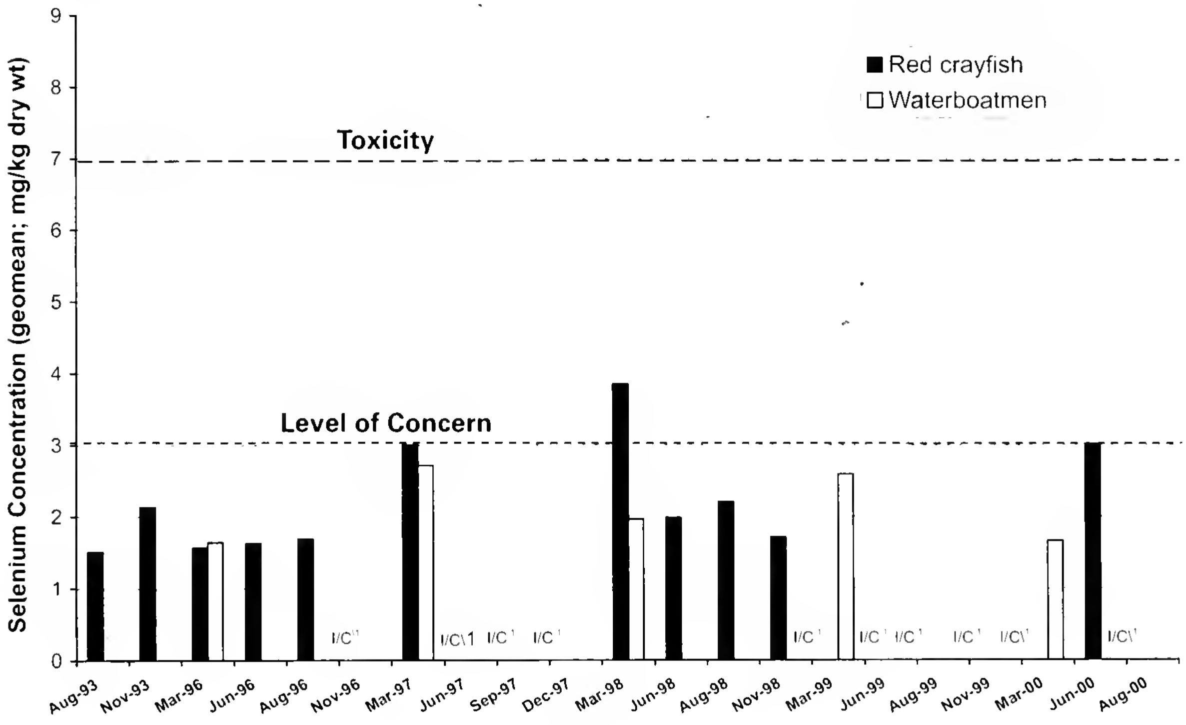
San Joaquin River below Mud Slough (Site H)

Site H is located at Hills Ferry on the San Joaquin River about two miles downstream of the Mud Slough confluence. This site represents the reach of the San Joaquin River most strongly influenced by agricultural drainwater discharges conveyed by the GBP. One of the environmental commitments of the GBP is that it will not worsen water quality in the San Joaquin River. For practical reasons of year-round accessibility, the site was located just upstream of the Merced River confluence; Merced River waters have relatively low concentrations of selenium. It is not unlikely that fish and invertebrates collected at Site H have previously moved into and foraged within reaches of the Merced River and diluted downstream reaches of the San Joaquin River, as well as the reach of the San Joaquin River where biota are collected. Additionally, it was determined in WY 1999 that seasonally high flows in the Merced River resulted in the branching of tributary flows that entered the San Joaquin River between Site H and Mud Slough. Due to the confounding influences on selenium body burdens caused by species-specific dispersal within River reaches surrounding Site H and seasonal inputs of Merced River tributary flows, selenium concentrations in fish and invertebrate tissues collected at this site may not be well correlated with water concentrations of selenium at this site.

Fish (Whole-Body)

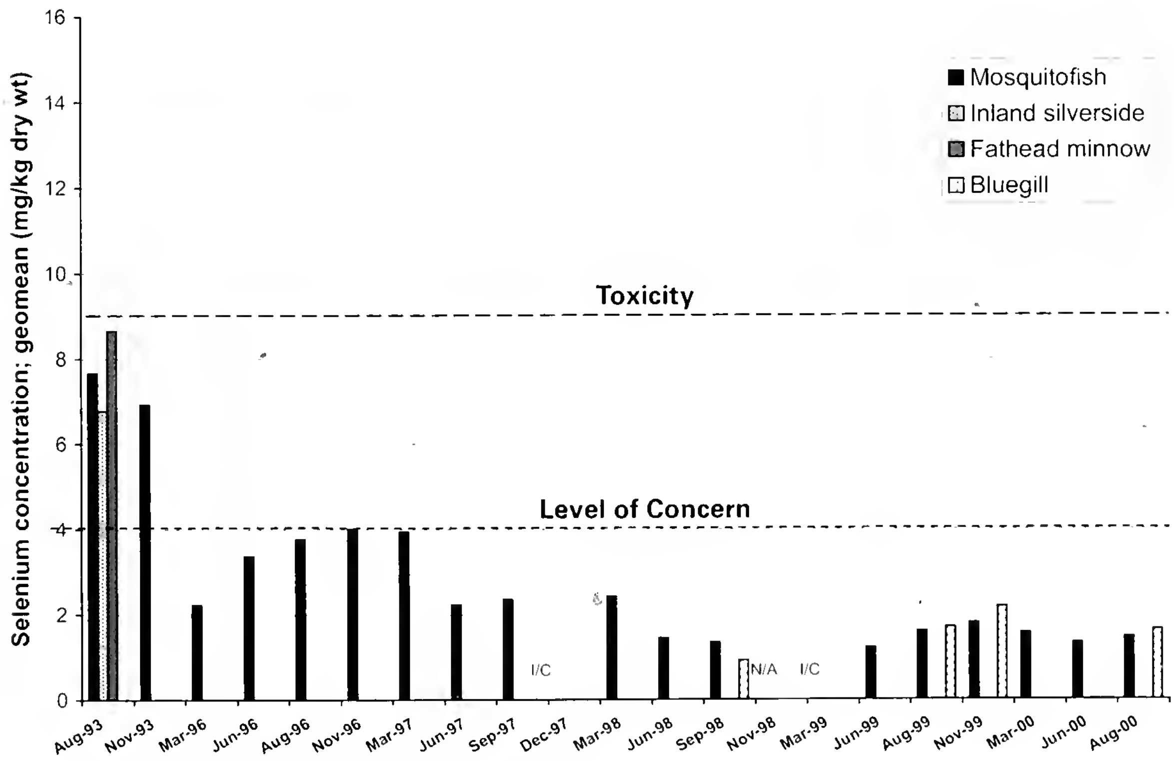
Selenium concentrations in whole-body fish composite samples collected during WY 2000 ranged from 1.34 to 3.54 mg/kg, with an average of 2.87 mg/kg (Figure 21). There has been a significant increase (p=0.013) in selenium concentrations in fish collected during WY 2000 (μ=2.87 mg/kg, n=16) from fish collected in WY 1999 (μ=2.32 mg/kg, n=18). Despite this, with the exception of mosquitofish collected in December 1997 with an average concentration of 4.13 mg/kg, selenium concentrations in all composite fish samples throughout the four years of GBP operation have remained below 4 mg/kg.

Figure 18. Selenium Concentration in Invertebrates from Mud Slough at Hwy 140 (Site E)



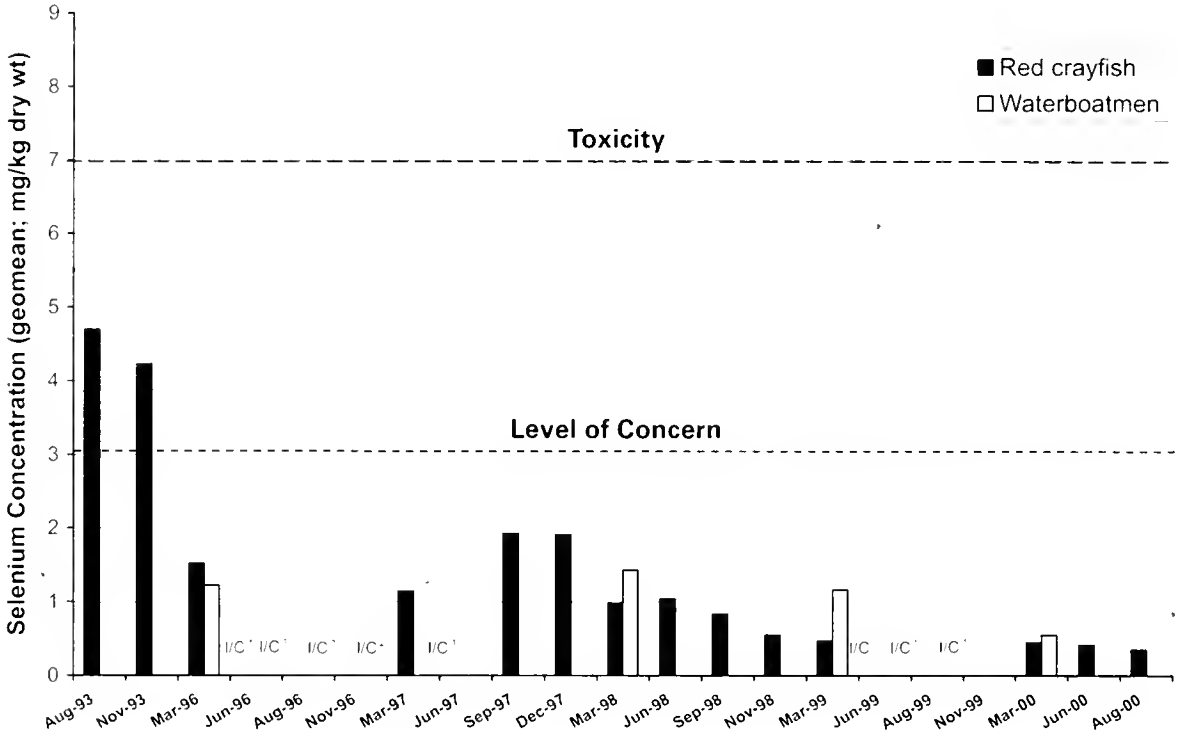
I/C\1 Insufficient Catch of Red Crayfish for Adequate Quarterly Sample

Figure 19. Selenium Concentrations in Whole-Body Fish Tissue from the San Joaquin River Upstream of the Mud Slough Confluence (Site G)



I/C. Insufficient Catch of Targeted Fish Species for Adequate Sample
N/A No Analysis of Collected Samples

Figure 20. Selenium Concentration in Invertebrates from the San Joaquin River Upstream of the Mud Slough Confluence (Site G)



I/C˙ Insufficient Catch of Red Crayfish for Adequate Quarterly Sample
I/C⁺ Insufficient Catch of Waterboatmen for Adequate Annual Sample

Invertebrates

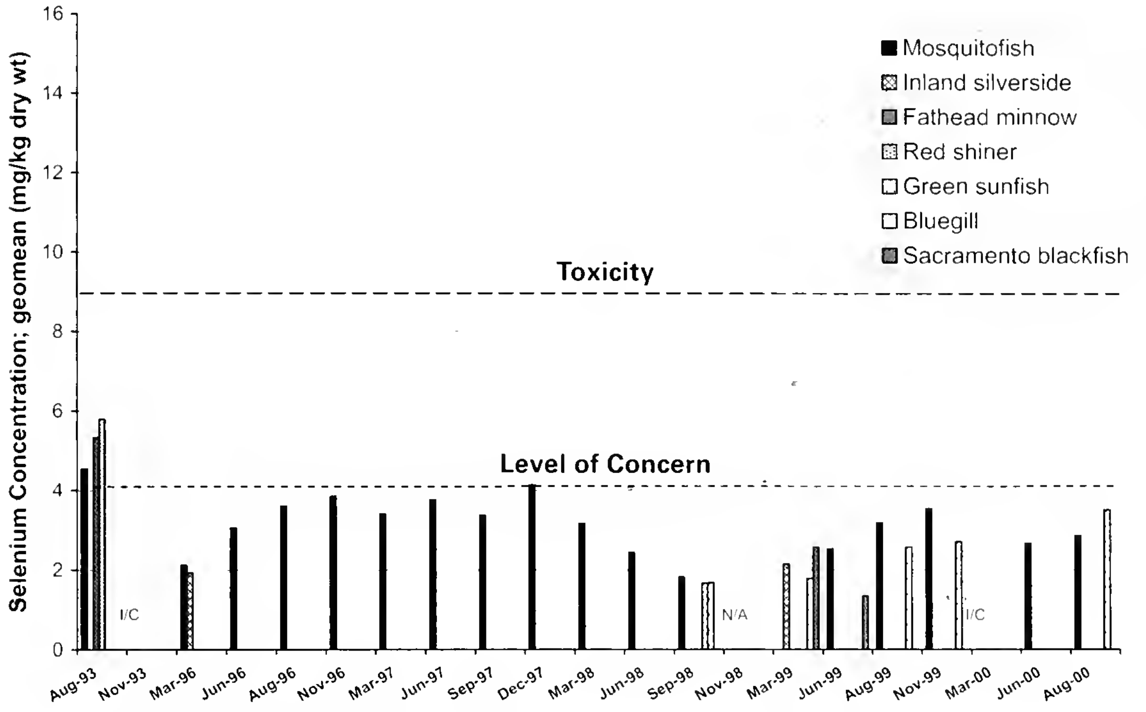
Selenium concentrations in red crayfish collected from this site in WY 2000 ranged from 0.65 mg/kg to 0.76 mg/kg (μ=0.67 mg/kg, n=4), remaining below the threshold of concern level (3 mg/kg) associated with no known adverse effects to higher order consumers (Figure 22). Selenium concentrations in waterboatmen collected in WY 2000 (μ=0.58, n=3) were significantly lower ($p < 0.0002$) than waterboatmen collected in WY 1999 (μ=1.39, n=3). Selenium concentrations in all invertebrate samples from this site have remained below 3 mg/kg throughout the four years of GBP operation.

Fish Communities Assessment

A fish communities assessment was conducted to describe fish assemblages based on species richness, abundance and community structure. Fish populations were sampled in Mud Slough at Highway 140 (Site E), San Joaquin River at Fremont Ford (Site G), and San Joaquin River below Mud Slough (Site H). Fish assemblages from Sites E, G, and H were compared both spatially and temporally to see if conditions for fish species in the San Joaquin River improved and conditions in Mud Slough degraded. We sampled in August and November 1993 and March, June, August/September 1996 - 2000. As the Grasslands Bypass Project began operation in September 1996, this sampling schedule provided a before-and-after picture of the fish communities at these sites. Only data collected with standardized sampling methodologies and effort were analyzed. A total of 32 fish species, and 2 hybrid sunfish, from 12 families, represented by 16,477 individuals, was collected during 5 pre-Project and 12 Project sampling events (Table 3). Native fish represented 2.5% of the catch by number and 28.0% of the catch by species.

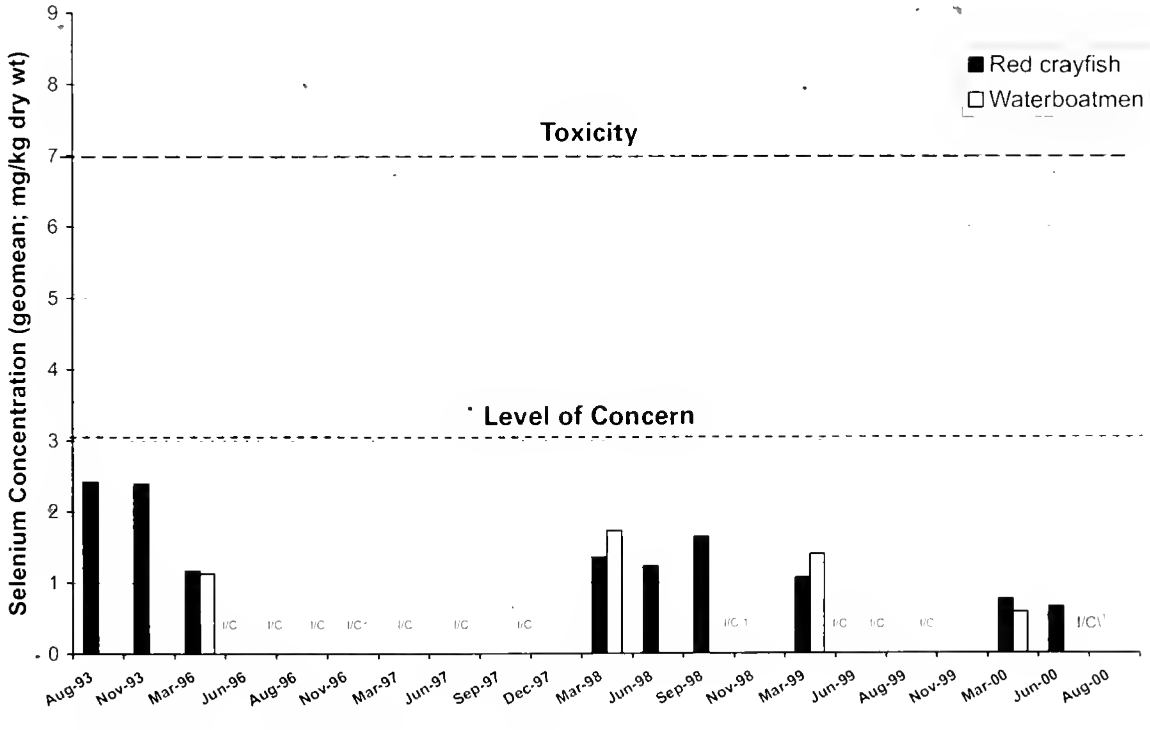
Salinity, temperature, dissolved oxygen, and pH were measured at each site where fish were sampled. Conductivity was lowest and water velocity was highest (California Data Exchange Center mean daily flow) in March and June 1998 as the result of high spring flows that year. Sacramento splittail were collected at the study sites only in June of 1998 (n=55 at Site E, n=36 at Site G, and n=17 at Site H). This was the most notable change in native fish abundance that we observed. The presence of splittail is considered with other evidence of good production of splittail in the San Joaquin River in 1998 to be the result of widespread flooding (Randy Baxter, DFG, personal communication). Splittail require flooded

Figure 21. Selenium Concentrations in Whole-Body Fish Tissue from the San Joaquin River Downstream of the Mud Slough Confluence (Site H)



I/C Insufficient Catch of Targeted Fish Species for Adequate Sample
N/A No Analysis of Collected Samples

Figure 22. Selenium Concentration in Invertebrates from the San Joaquin River Downstream of the Mud Slough Confluence (Site H)



I/C[1] Insufficient Catch of Red Crayfish for Adequate Quarterly Sample
I/C[2] Insufficient Catch of Waterboatmen for Adequate Annual Sample

vegetation for spawning and as foraging areas for young (Caywood 1974).

Chinook salmon abundance was highest in March 1998 when 19 were caught (and released) at Site H. Except for the capture of one fish in March 1997 and 1999 at Site H, no other chinook salmon were caught. The increase in captured juvenile chinook salmon may indicate higher production and/or survival in 1998, or high flows washed fish out of the tributaries at the time we were sampling. Annual spring abundance of fry and survival of juvenile chinook salmon in the delta appear to be influenced by river flow rate and temperature; survival and abundance decreased as flow rates decreased and temperatures increased (Kjelson, Raquel, and Fisher 1982 and Brandes and McLain 2000).

The Sacramento blackfish was the most abundant native fish throughout the study, probably due to its tolerance of poor water quality (Brown and Moyle 1993). Other native species collected were prickly sculpin, Sacramento blackfish, Sacramento pikeminnow, and Sacramento sucker.

Assessment of fish community structure generates inference based on the concept that structure implies function. Habitat degradation can result in a shifting availability of food resources, such as reductions in sensitive macroinvertebrate communities, increases in phytoplankton production relative to nutrient loadings into a stream, and loss or replacement of important forage fish. Increased presence of tolerant fish species, and species with less specialized feeding habits, such as omnivores, are common in degraded streams or streams of low habitat complexity. Diverse fish assemblages which include viable populations of top carnivore species, specialized invertivores, as well as omnivores, are suggestive of a healthy community able to support representative species from all trophic guilds. Examination of change in fish species assemblages over time, using linear regression analysis (after arcsine transformation of the trophic level properties) revealed no time trends ($p>0.05$, Figures 23-25). Although the data to date do not reveal a statistically significant alteration in trophic composition of the entire fish assemblage over time, there may be a trend developing of decreasing omnivorous species and increasing invertivorous species at Site G (Figure 24), with the opposite trend occurring at Site E (Figure 23). Invertivores and omnivores were dominant at all three sites and had complementary distributions. The time trend in total anomalies for the various groups of fishes at each site also was not significant (F-test $p>0.05$, Figure 26).

During September and October 1997, about one year after the reopening of the SLD, Saiki (1998) sampled fish at 13 sites in the Grassland area. These sites correspond to locations he had surveyed more than a decade earlier (Saiki 1986). Some of his sample sites were the same as, or close to, GBP monitoring sites, but others

Figure 23. Percent Abundance of Trophic Classifications Over Time at Site E

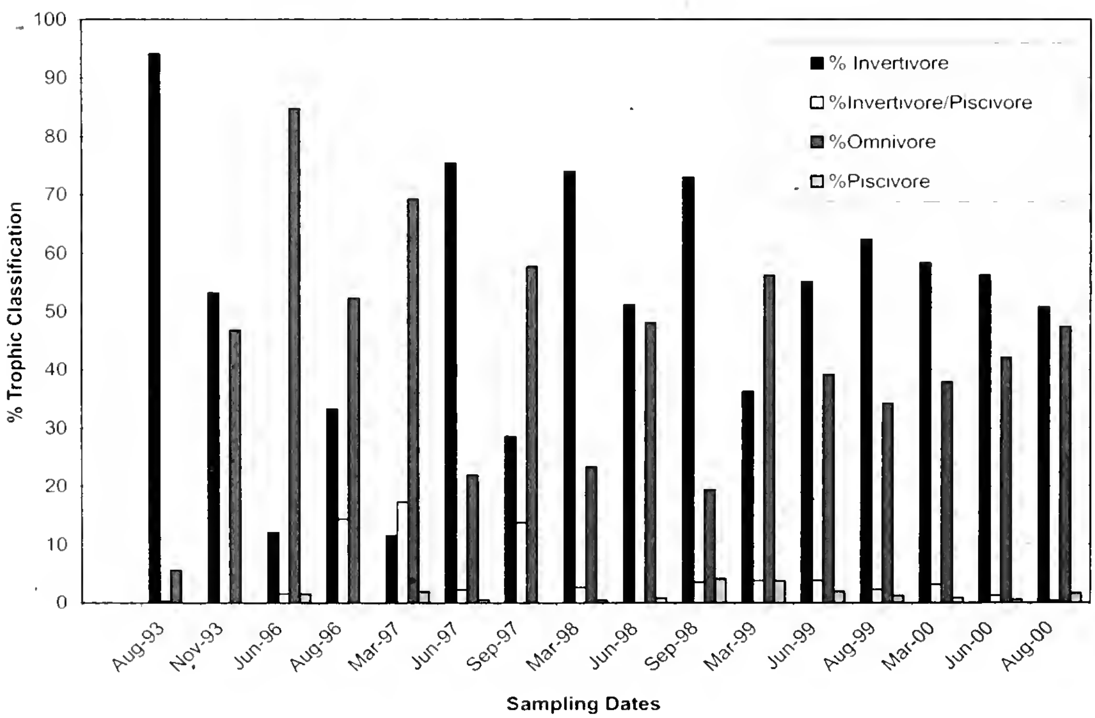


Table 3. Fishes Caught from Grassland Bypass Project Stations E, G, and H in Decreasing Order of Numerical Abundance

Species	Number	Origin	Trophic Classification	Tolerance
Mosquitofish, *Gambusia affinis*	5731	Introduced	I	T
Inland silverside, *Menidia beryllina*	3280	Introduced	I	M
Fathead minnow, *Pimephales promelas*	1983	Introduced	O	T
Carp, *Cyprinus carpio*	1620	Introduced	O	T
White catfish, *Ameiurus catus*	665	Introduced	I/P	T
Bluegill, *Lepomis macrochirus*	546	Introduced	I	T
Red shiner, *Cyprinella lutrensis*	507	Introduced	O	T
Largemouth bass, *Micropterus salmoides*	302	Introduced	P	T
Threadfin shad, *Dorosoma petenense*	298	Introduced	I	M
Goldfish, *Carassius auratus*	294	Introduced	O	T
Redear sunfish, *Lepomis microlophus*	228	Introduced	I	M
Green sunfish, *Lepomis cyanellus*	218	Introduced	I/P	T
Sacramento blackfish, *Orthodon microlepidotus*	209	Native	O	T
Channel catfish, *Ictalurus punctatus*	172	Introduced	I/P	M
Sacramento Splittail, *Pogonichthys macrolepidotus*	108	Native	O	M
Bigscale logperch, *Percina macrolepida*	68	Introduced	I	T
Black crappie, *Pomoxis nigromaculatus*	53	Introduced	I/P	M
Prickly sculpin, *Cottus asper*	25	Native	I	M
Sacramento sucker, *Catostomus occidentalis*	25	Native	O	M
Striped bass, *Morone saxatilis*	24	Introduced	P	M
Sacramento squawfish, *Ptychocheilus grandis*	22	Native	I/P	M
Chinook salmon, *Oncorhynchus tshawytscha*	21	Native	I	I
Brown bullhead, *Ameiurus nebulosus*	21	Introduced	I/P	T
Smallmouth bass, *Micropterus dolomieui*	19	Introduced	I/P	M
American shad, *Alosa sapidissima*	9	Introduced	I	M
White crappie, *Pomoxis annularis*	8	Introduced	I/P	T
Black bullhead, *Ameiurus melas*	7	Introduced	I/P	T
Hitch, *Lavinia exilicauda*	4	Native	O	M
Tule perch, *Hysteocarpus traski*	4	Native	I	I
Warmouth, *Lepomis gulosus*	2	Introduced	I	M
Golden Shiner, *Notemigonus crysoleucas*	1	Introduced	I	M
Riffle sculpin, *Cottus gulosus*	1	Native	I	M

Trophic Classification: O=Omnivore, I=Invertivore, P=Piscivore, I/P=Invertivore/Piscivore
Tolerance to environmental degradation: I=Intolerant, M=Moderately Tolerant, T=Tolerant

(Brown and Moyle, 1992, Moyle, 1976, McGinnis, 1984)

were located in areas not monitored by the GBP. The SLD was the only site in the area that lacked bluegill and goldfish, and overall, fewer species of fish were found in the SLD than at any other site. However, Saiki did not find any significant difference in community structure related to the proportion of drainwater present. To explain this, he noted that all waterways in the area are overwhelmingly dominated by introduced species having broad environmental tolerances. Saiki's findings agree with those of the GBP biological monitoring program. After 3 years of Project operation, there is no evidence that any significant alterations in fish species assemblages are occurring in response to either water quality improvements or degradations within the Project area. Nonetheless, community assessment methodology may lack the power to detect all but the most pronounced alterations in community structure.

During the fourth year of Project operation, selenium concentrations in all carp fillets from Site E remained below the 2 mg/kg health screening level, ranging from 0.72 mg/kg to 1.71 mg/kg (Figure 27). Carp collected from Mud Slough at Site E exceeded the 2 mg/kg wet wt selenium health screening level once during WY 1997, peaking at 2.64 mg/kg, and once during WY 1998, peaking at 2.46 mg/kg. During all other sample periods throughout the first three years of GBP operation, samples of carp have remained below the 2 mg/kg health screening level. Selenium concentrations in carp fillets from Sites G (μ=0.42 mg/kg wet wt, n=12) and H (μ=0.49 mg/kg wet wt, n=12) on the San Joaquin River have remained consistently below the 2 mg/kg health screening level throughout all four years of GBP opera-

Figure 24. Percent Abundance of Trophic Classifications Over Time at Site G

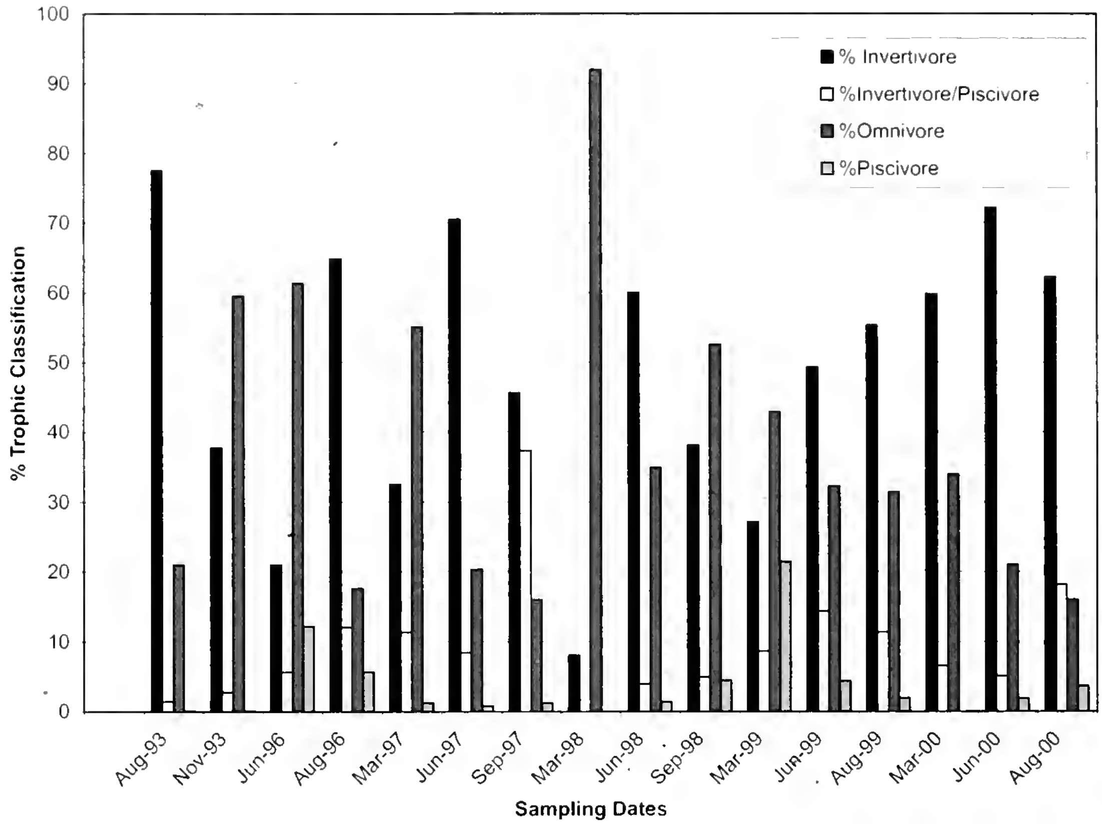


Figure 25. Percent Abundance of Trophic Classifications Over Time at Site H

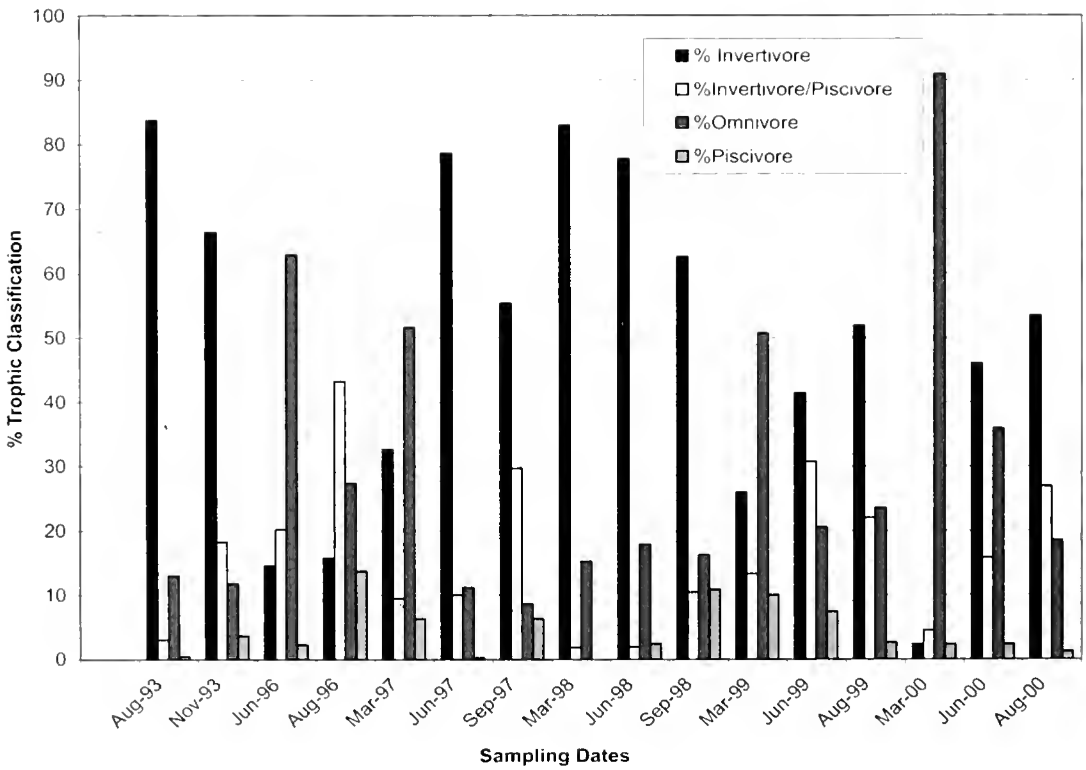
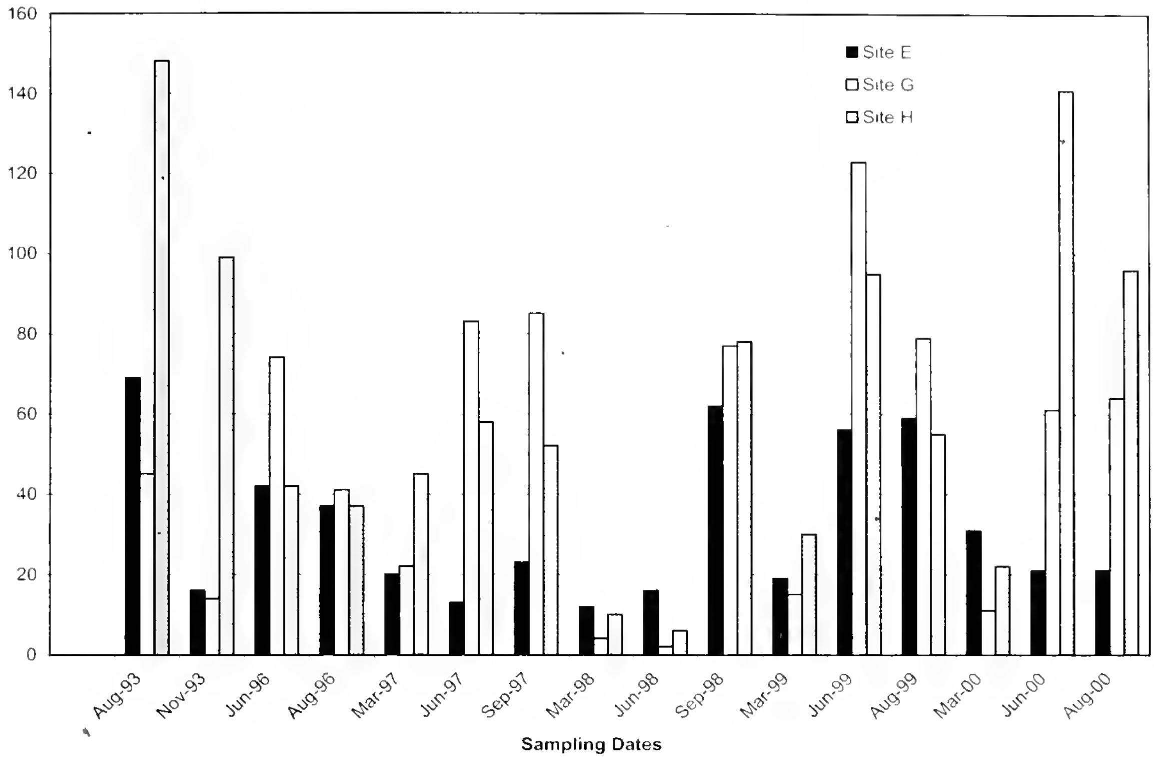


Figure 26. Total Anomalies in all Fish Species Caught from Sites E,G, and H



tions (Figures 28 and 29). During the first year of the GBP, samples of white catfish collected in November 1996 and June 1997, and samples of largemouth bass (three composite samples of five individuals each) collected in June 1997 were also below the 2 mg/kg health screening level (Figure 29).

Selenium in Plants

Selenium in plant material that is preferred by waterfowl (seed heads) was analyzed in samples collected in WY 2000 and in some samples archived from previous years (Figure 30). Selenium concentrations were higher in plants along Mud Slough downstream of the San Luis Drain (Sites D and I) than at the upstream site on Mud Slough (Site C) and the Salt Slough site (Site F), but at all sites concentrations were well below the threshold of concern for reproductive effects on waterfowl due to dietary exposure (3 mg/kg). These data suggest that birds in this area are at greater risk due to eating invertebrates and fish than from eating plants.

A single egg was randomly collected and analyzed from each of thirty-two bird nests in the Grassland area in 2000; in addition one mallard "dump" egg (not in nest) collected along the San Luis Drain was analyzed (Figure 31). Species sampled included killdeer, American avocet, mallard, gadwall, green-winged teal, northern harrier, barn swallow and Brewer's blackbird. To provide a reference baseline for comparison with eggs collected in the Mud and Salt Slough areas, eggs were also collected in 2000 from the Merced National Wildlife Refuge on the east side of the San Joaquin River, where environmental selenium is low. The selenium concentrations in all eggs analyzed were within the "no effect" range of concentrations (<6 mg/kg). Selenium concentrations in eggs analyzed from the Salt Slough area (geometric mean 2.6 mg/kg, n=8) were not significantly different from those analyzed from the Mud Slough area (geometric mean 3.2 mg/kg, n=18, p=0.17), and not significantly different from those from Merced Refuge (geometric mean 2.2 mg/kg, n=7, p=0.22). However, concentrations in Mud Slough eggs were significantly higher than in Merced Refuge eggs (p=0.0004). In both the Salt Slough and Mud Slough areas, there have been no clear trends in selenium

Figure 27. Se Concentration in Fish Muscle Tissue from Mud Slough at Hwy 140 (Site E)

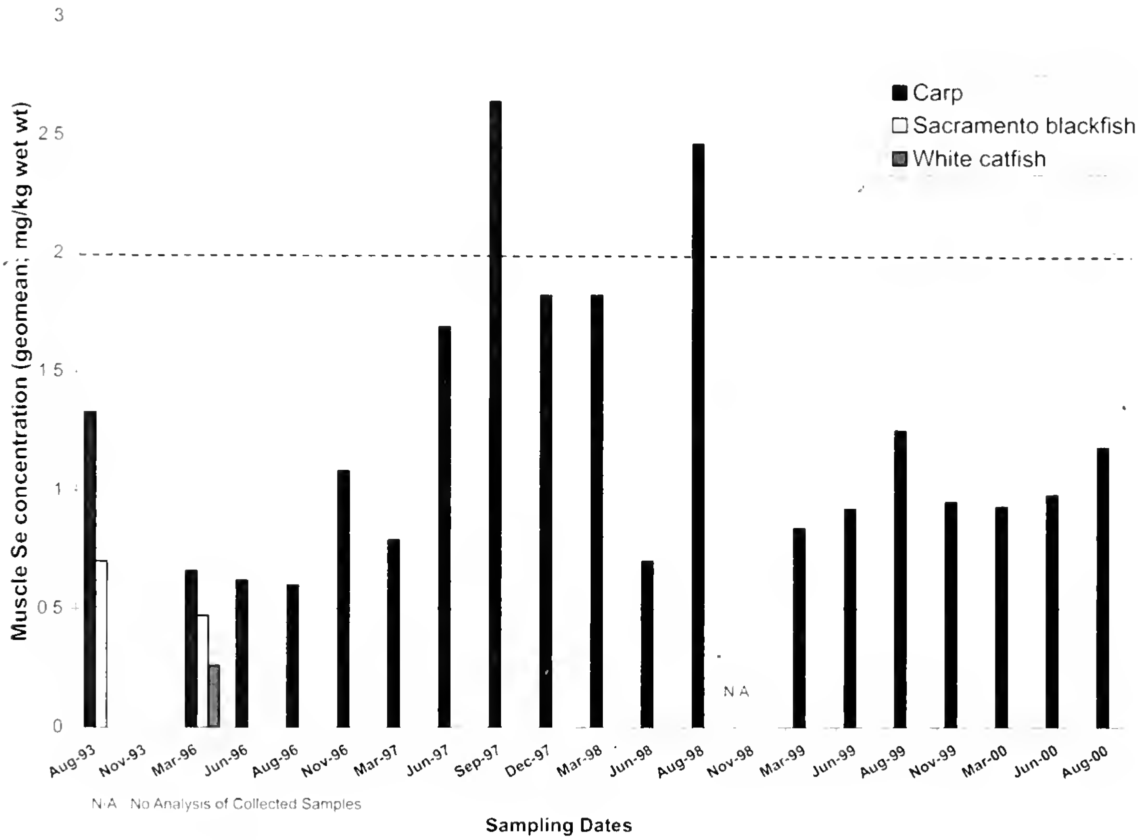


Figure 28. Se Concentration in Fish Muscle Tissue from the San Joaquin River Upstream of the Mud Slough Confluence (Site G)

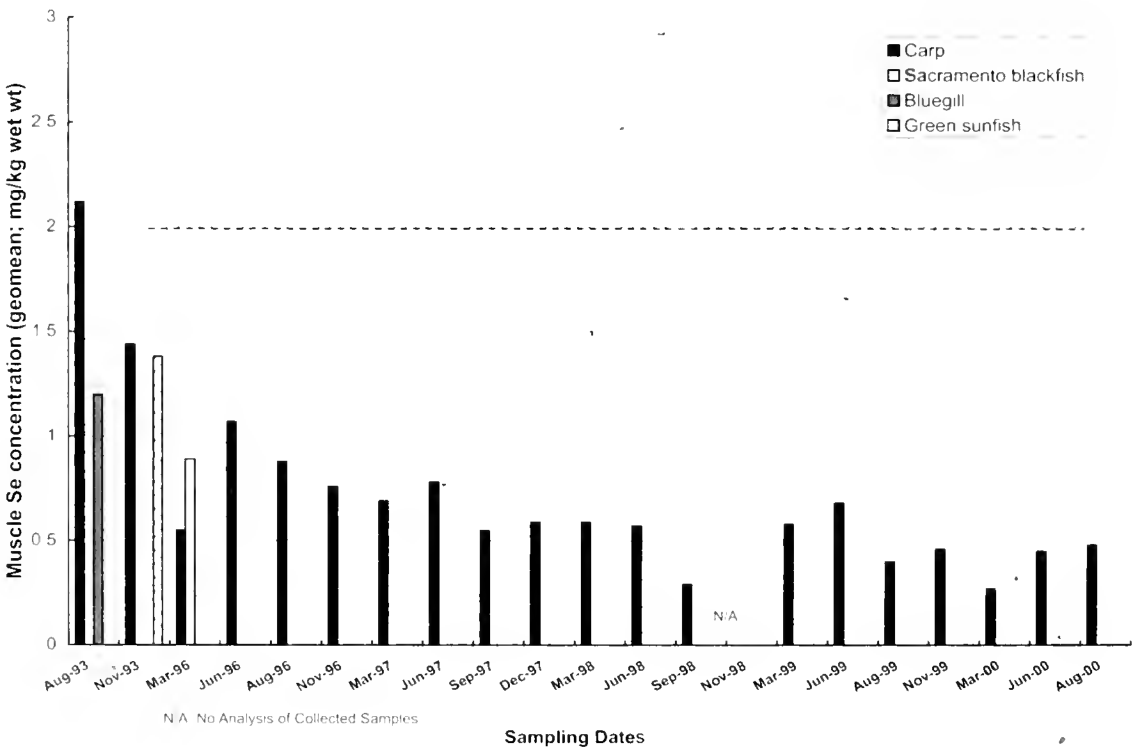


Figure 29. Selenium Concentration in Fish Muscle Tissue from the San Joaquin River Downstream of the Mud Slough Confluence (Site H)

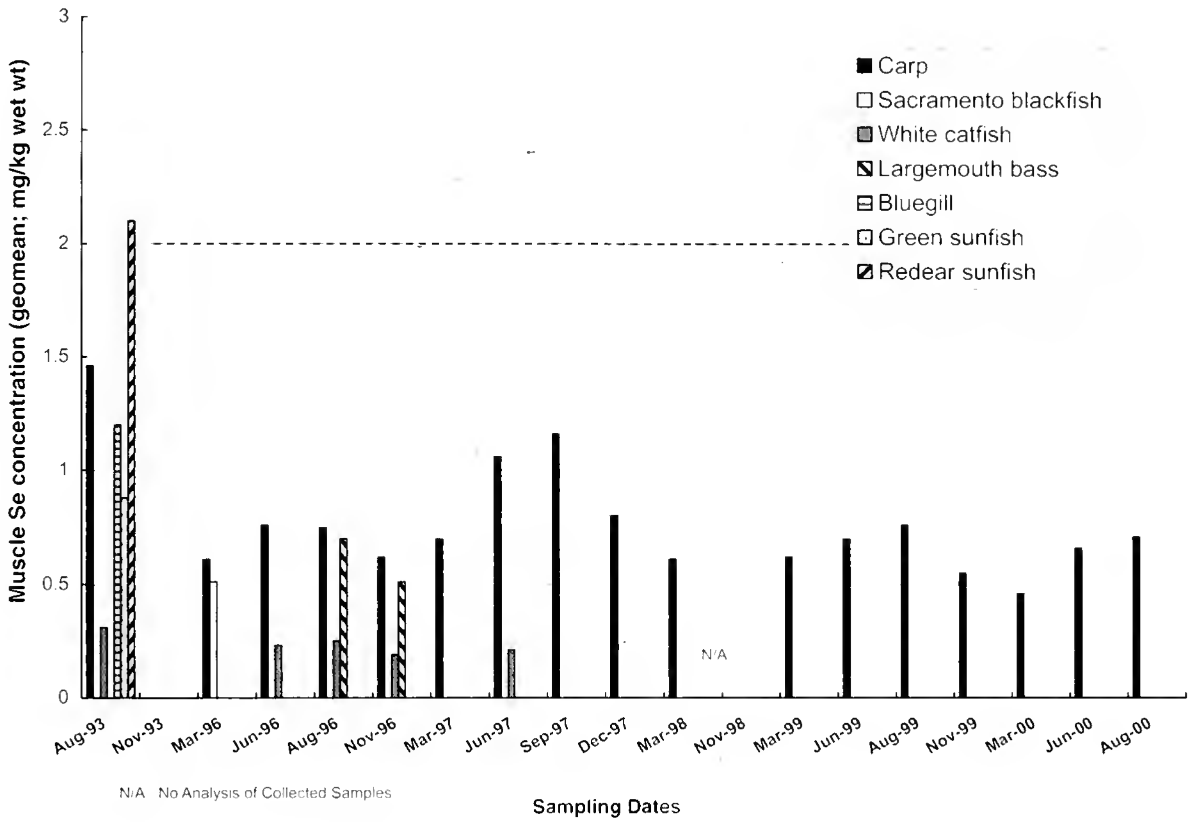
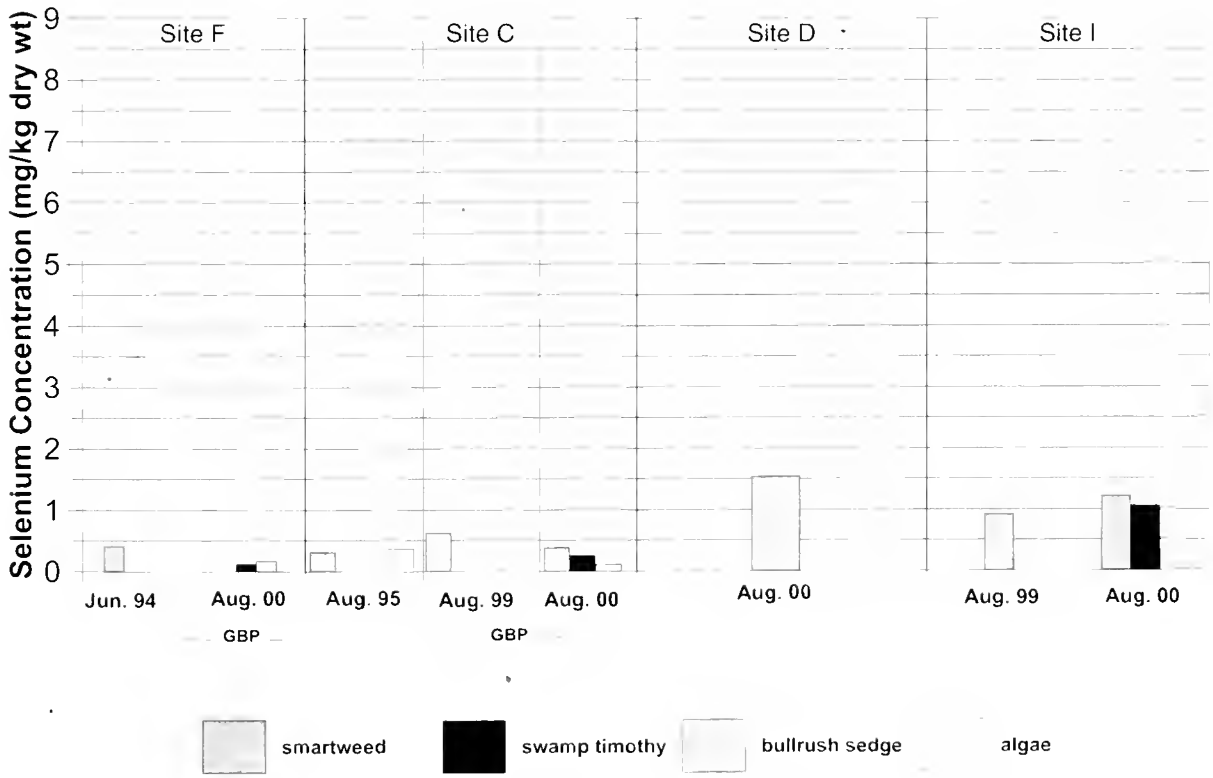
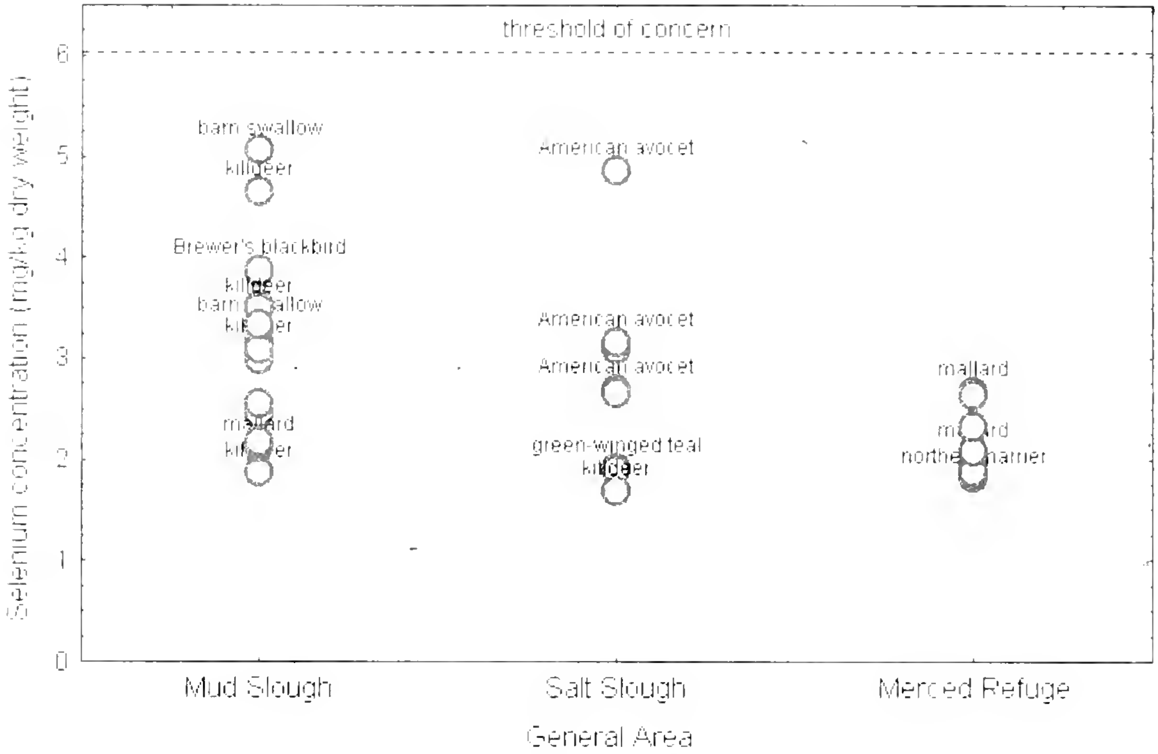


Figure 30. Selenium Concentrations in Plants



* Calculated from wet wt concentration using average percent moisture of similar samples

Figure 31. Bird Eggs 2000



concentrations in killdeer and duck eggs since the nesting season of 1996, before the start of the GBP (Figures 32-35), probably reflecting the fact that the exposure of these birds is due not so much to the sloughs as to wetlands that have been supplied throughout this period with water that is of better quality than that found in the sloughs.

To provide an estimate of ecosystem-level effects of selenium, Lemly (1995, 1996) developed an aquatic hazard assessment procedure that sums the effects of selenium on various ecosystem components to yield a single characterization of overall hazard to aquatic life. Lemly's procedure applied to Mud Slough downstream of the SLD outfall indicated that the hazard to aquatic life in the affected portion of Mud Slough continued to be "high" in WY 2000 (Table 4). In the Salt Slough area, the Lemly index remained "low" in WY 2000 (Table 4). A Lemly index was not determined for San Joaquin River sites due to lack of sufficient sample of invertebrates and because bird eggs, one component of the index, were not sampled there.

Samples of seedheads from plants (smartweed, swamp timothy, bullrush sedge) collected in August 2000 from Sites C, D, I, and F were analyzed for boron. At Site C, two of three samples (20.8, 34.6, and 38.8 mg/kg) exceeded the threshold of concern for boron in plants as diet (30 mg/kg, Table 2). At Sites D, I, and F, all samples exceeded the threshold of concern (Site D: 73.8 mg/kg; Site I: 89.2, 79.3, and 62.0 mg/kg; Site F: 41.4 and 45.9 mg/kg).

Boron concentration in a single composite sample of 100 female mosquitofish from Site C in August 2000 was 3.4 mg/kg. A single composite sample of 21 female mosquitofish from Site D in August 2000 had a boron concentration of 6.85 mg/kg. A single composite sample of 25 female mosquitofish from Site F in August 2000 had a boron concentration of 1.3 mg/kg. Risk guidelines for interpreting these fish tissue concentrations are not currently available.

We greatly appreciate the assistance provided in the field by Ryan Olah, Marla Macoubrie, Doug Morrison, Cathy Johnson, and Kyle Merriam, from the Sacramento Fish

Figure 32. Killdeer Eggs Near Salt Slough

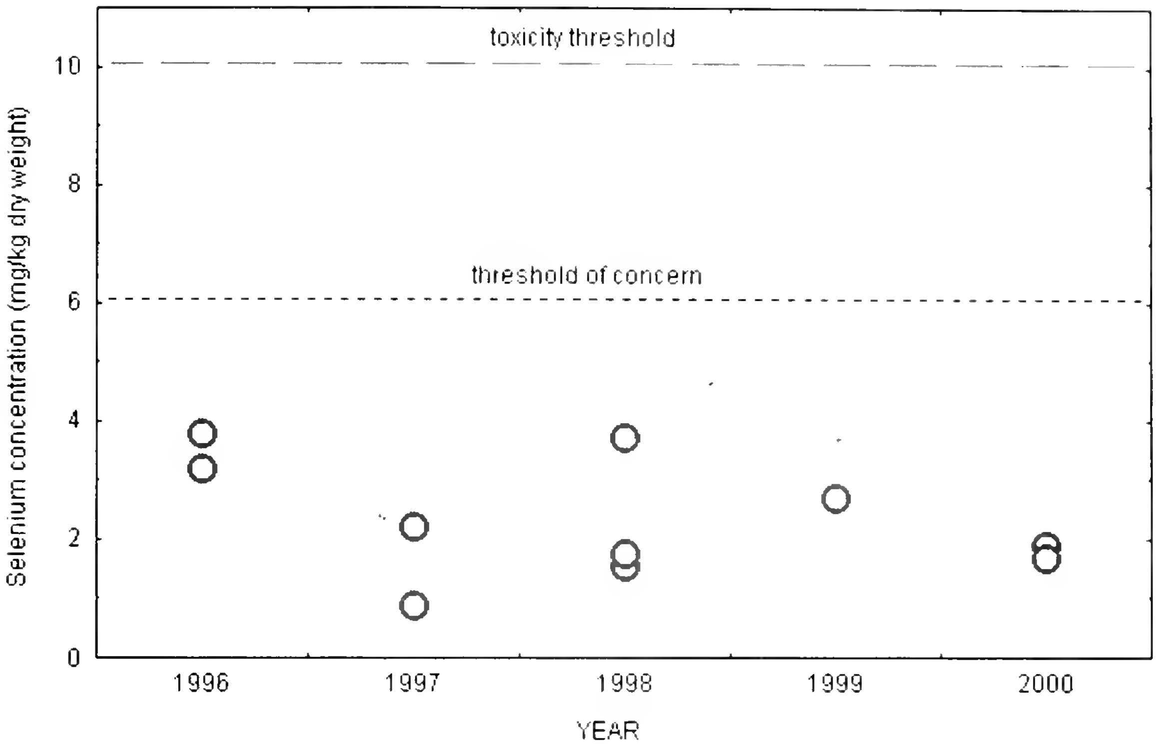


Figure 33. Ducks Eggs in Salt Slough Area

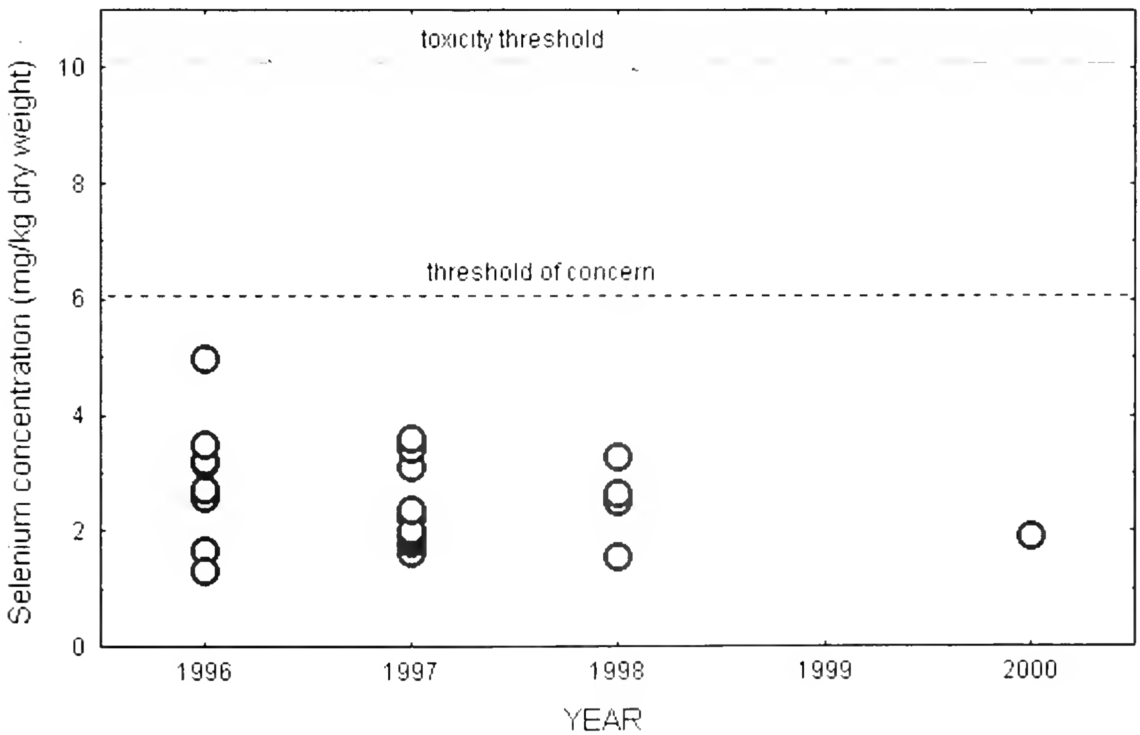


Figure 34. Killdeer Eggs Near Mud Slough

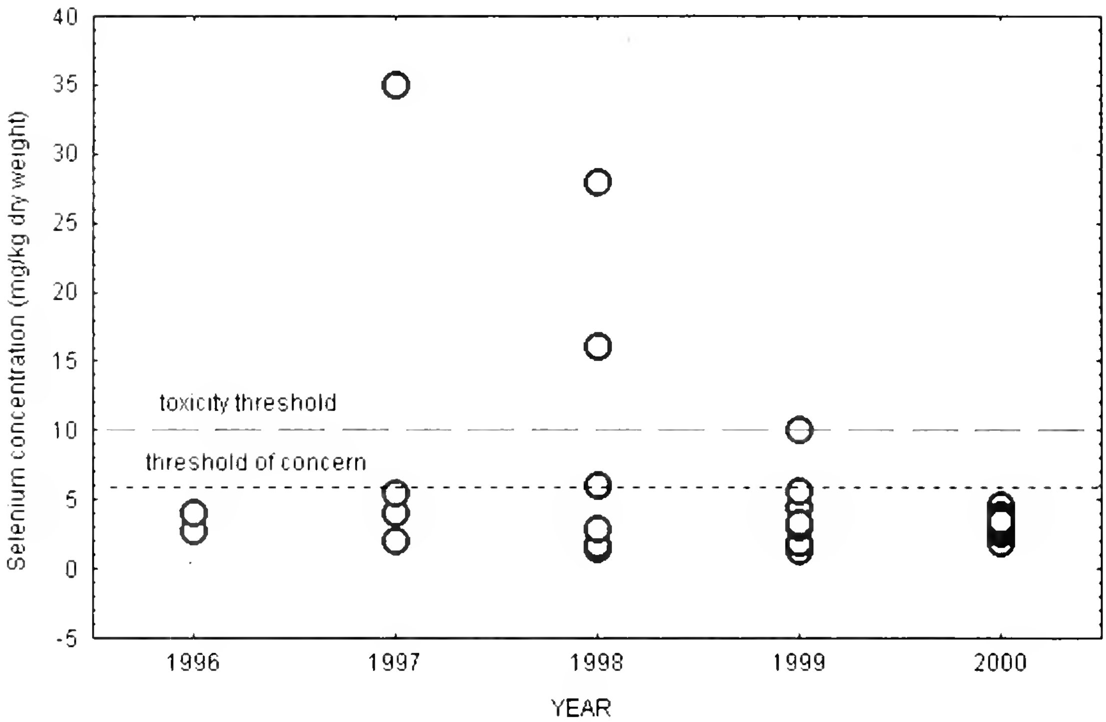
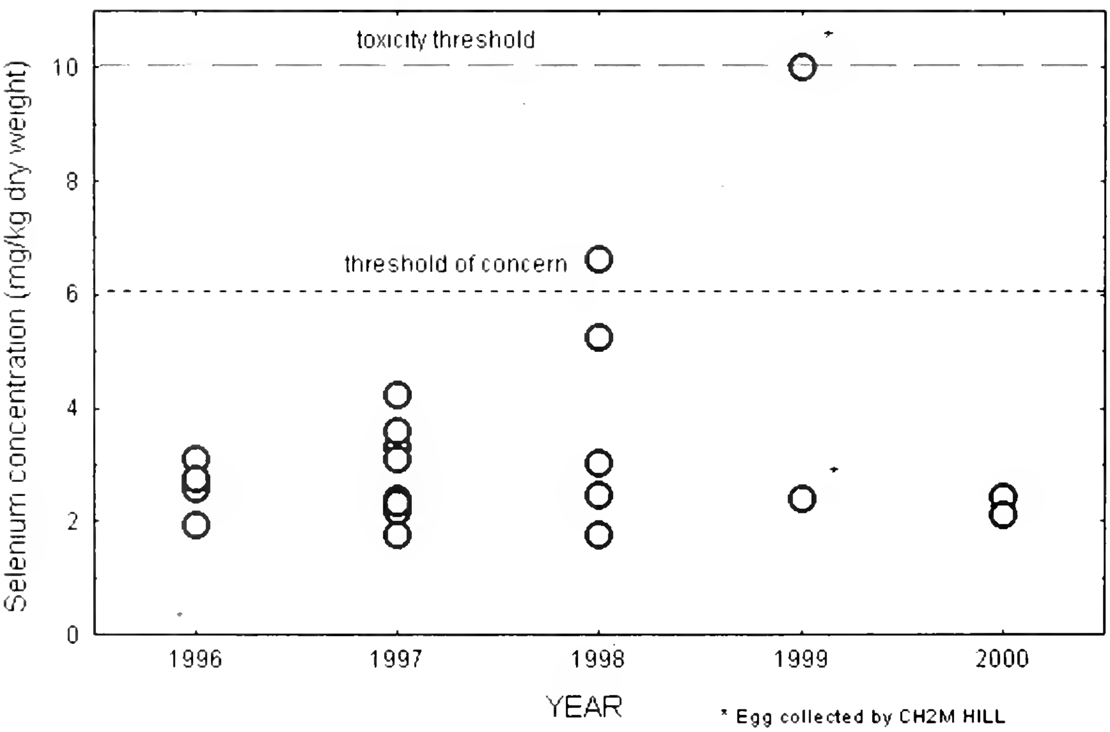


Figure 35. Duck Eggs in Mud Slough Area



and Wildlife Service Office, by Derek Milsops, Sharon Bakeman, Erin Crystal, Tim Keldsen,Tina Chouinard, and Karen Harvey from the San Luis National Wildlife Refuge Complex. Chris Eacock, Michelle Prowse, Demetria Adams and Helen Beckon from the Bureau of Reclamation also kindly assisted us in the field. We are also grateful for the field assistance provided by Curtis Hagen, and Todd Newhouse from the Central Valley Bay-Delta Branch of the California Department of Fish and Game.

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Table 4. Aquatic Hazard Assessment o Selenium in Mud and Salt Slough areas

	BEFORE PROJECT 1995 Sept 1996			SINCE PROJECT WY 1997			WY 1998			WY 1999			WY 2000		
	concentration	score	hazard	concentration	score	hazard	concentration	score	hazard	concentration	score	hazard	concentration	score	hazard
Mud Slough below Drain outfall															
Water	19.4 µg/l	5	high	79.6 µg/l	5	high	104.0 µg/l	5	high	50.7 µg/l	5	high	66.0 ug/l	5	high
Sediment	0.4 µg/g	1	none	0.76 µg/g	1	none	2.0 µg/g	3	low	4.8 µg/g	5	high	4.4 µg/g	5	high
Invertebrates	1.6 µg/g	1	none	3.3 µg/g	3	low	11 µg/g	5	high	7.0 µg/g	5	high	15.3 µg/g	5	high
Fish eggs	14.2 µg/g	4	moderate	56.1 µg/g	5	high	34.2 µg/g	5	high	39.6 µg/g	5	high	46.5 µg/g	5	high
Bird eggs	3.12 µg/g	2	minimal	4.4 µg/g	2	minimal	6.6 µg/g	3	low	10 µg/g	3	low	5.1 µg/g	3	low
TOTAL		**13**	moderate		**16**	high		**21**	high		**23**	high		**23**	high
Salt Slough															
Water	37.8 µg/l	5	high	3.4 µg/l	4	moderate	5.1 µg/l	5	high	<1.5 µg/l	2	minimal	1.7 µg/l	2	minimal
Sediment	0.8 µg/g	1	none	0.94 µg/g	1	none	2.1 µg/g	3	low	0.93 µg/g	1	none	0.68 µg/g	1	none
Invertebrates	4.7 µg/g	4	moderate	2.6 µg/g	2	minimal	3.15 µg/g	3	low	2.8 µg/g	2	minimal	2.7 µg/g	2	minimal
Fish eggs	28.1 µg/g	5	high	17.8 µg/g	4	moderate	12.9 µg/g	4	moderate	11.2 µg/g	4	moderate	14.5 µg/g	4	moderate
Bird eggs	5.2 µg/g	3	low	3.6 µg/g	2	minimal	5.72 µg/g	2	minimal	2.7 µg/g	1	none	4.9 µg/g	2	minimal
TOTAL		**18**	high		**13**	moderate		**17**	high		**10**	low		**11**	low

Hazard scale for total score 5 no hazard 6-8, minimal hazard 9-11 low hazard 12-15 moderate hazard 16-25 high hazard

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[illegible]

WY 2000 maximum contaminant concentration data used for the Lemly Index (Table 4)

Mud Slough (SLD, D, I, and E)
water: 4 May 2000 Site D 66.0 µg/l weekly sample (CVRWQCB web)
sediment: 7 June 2000 Site I 0-3 cm 4.4 µg/g (USBR)
inverts: red crayfish 22 August 2000 Site I 15.3 µg/g (Sample ID I00A06) n=1
fish: inland silverside 22 August 2000 Site I 14.11 µg/g whole body x 3.3 = 46.5 µg/g in eggs (Sample ID I00A07) n=16
bird eggs: barn swallow 20 April 2000 SLD 5.1 µg/g (Sample ID SLD00A02) n=1

Salt Slough
water: 15 March 2000 Site F 1.7 µg/l weekly sample (CVRWQCB web)
sediment: 27 September 2000 Site F (3-8 cm): 0.68 µg/g (USBR)
inverts: red crayfish 16 March 2000 Site F 2.7 µg/g (Sample ID F00M01) n=6
fish: green sunfish 15 November 2000 Site F 4.4 (whole body) x 3.3 = 14.5 µg/g in eggs (Sample ID F99N15) n=1
bird eggs: American avocet 23 May 2000 4.9 µg/g (Sample ID SL00M05) n=1

Biomonitoring Program

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Block Environmental Services

GRASSLAND BYPASS

PROJECT

Introduction

The Grassland Bypass Project (GBP) toxicity monitoring program was implemented to evaluate potential adverse effects to test organisms exposed to agricultural drain water from the San Luis Drain (SLD; Station B) and Mud Slough (Station D). An evaluation was also made for Mud Slough (Station C) above the influence of the SLD and for Salt Slough (Station F). Each site was compared with responses produced from ambient control water (Delta Mendota Canal). The data can then be used to assess contaminant exposures both temporally and spatially within the Project area and to identify trends.

The toxicity monitoring program consisted of monthly controlled laboratory testing. These tests were conducted by Block Environmental Services (BES) Bioassay Laboratory Division, under the guidance of the San Luis & Delta Mendota Water Authority and with quality assurance/quality control (QA/QC) assistance from the U.S. Environmental Protection Agency (USEPA). Selenium and sulfate concentrations were also determined from water samples collected for each toxicity testing event. These chemical analyses were performed by the U.S. Bureau of Reclamation (USBR) contract laboratories. Each of the toxicity tests was performed using three separate grab samples collected on Day 0, Day 3, and Day 5 of the 7-day testing period. The WY 2000 annual data are also compared with the WY 1997, WY 1998, and WY 1999 annual data, where possible.

Materials and Methods

The laboratory toxicity tests evaluated three different species using short-term chronic testing procedures (USEPA, 1987; 1994). Grab samples were collected from Stations B, C, D, F, and the Delta Mendota Canal (DMC) for each monthly testing period. The test species included the freshwater alga *Selenastrum capricornutum*, the fathead minnow *Pimephales promelas*, and the daphnid invertebrate *Daphnia magna*. Each test was performed using 100% sample versus the DMC ambient control except for Station B, where additional *Selenastrum capricornutum* definitive tests were conducted. All toxicity test results were analyzed using the software program Toxicity Information Management System (TOXIS, Version 2.5, EcoAnalysis, Inc.). TOXIS was used to determine if there was a statistically significant reduction ($p<0.05$) in the site test response versus the ambient control response during each monthly testing period (USEPA, 1994).

In order to assess independently the health of the test organisms and laboratory performance, a concurrent reference toxicant test was conducted for each of the test species during the monthly testing periods. The reference toxicant test was conducted using a dilution series of the toxicant in laboratory control water. The toxicity endpoints from the reference toxicant tests of each test method were plotted on a running control chart of the last 20 tests. The mean and upper and lower control limits (± 2 standard deviations) were recalculated with each successive test result. The outliers, which were values falling outside the upper and lower control limits, and trends of increasing or decreasing sensitivity, were identified. At the $p= 0.05$ probability level, one in 20 tests (5%) would be expected to fall outside of the control limits by chance alone.

The USEPA conducted toxicity tests concurrent with the BES laboratory during the April 2000 sampling event for the fathead minnow and algae. Testing was not available for comparison with *Daphnia magna*.

Water samples for chemical analysis were collected during each toxicity testing sampling event. Samples for selenium and sulfate were analyzed by the USBR contract laboratories (Tables 1b, 2b, Figures 21, 22). Other water chemistry (performed by BES) included temperature, dissolved oxygen (DO), pH, conductivity, salinity, ammonia, total chlorine, hardness, alkalinity, and total suspended solids. Samples were also analyzed for DO, pH, conductivity and salinity in the field during collection of the first of the three samples collected for each monthly sampling event

Except as noted above, specific sampling and testing protocols for each procedure may be found in Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project (USBR et al., 1996) and the Quality Assurance Project Plan (Entrix, Inc., 1997).

Results

Toxicity testing, as described in the Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project (USBR et al., 1996) began in October 1996. Data for the three previous years of the toxicity monitoring program may be found in the Annual Reports (USBR, 1998, 1999 and 2000). The results from the fourth year of the toxicity monitoring program are presented in Tables 1 through 12. Figures 1 through 20 present data graphically for all three years of monitoring.

Water chemistry data measured in the laboratory comparing each of the stations are found in Figures 21–30. Tables A3-A12 summarize the field chemistry data; Table 10 provides information on the sample collection depth.

Figure 1
Station B Compared to Delta Mendota Canal—Chronic Endpoints

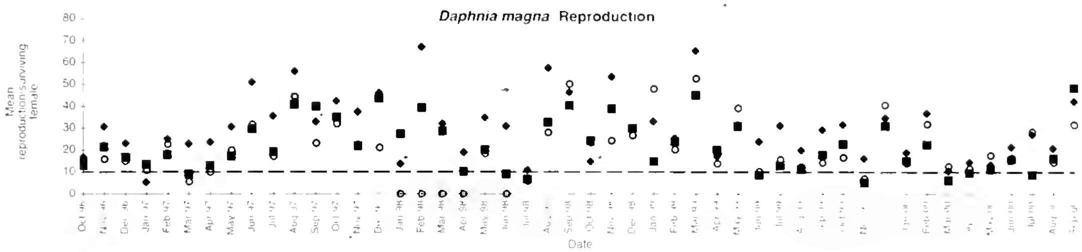


Figure 2
Station B Compared to Delta Mendota Canal—Chronic Endpoints

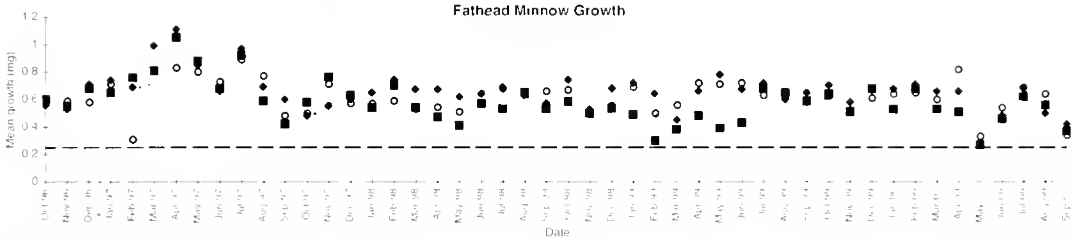


Figure 3
Station B Compared to Delta Mendota Canal—Chronic Endpoints

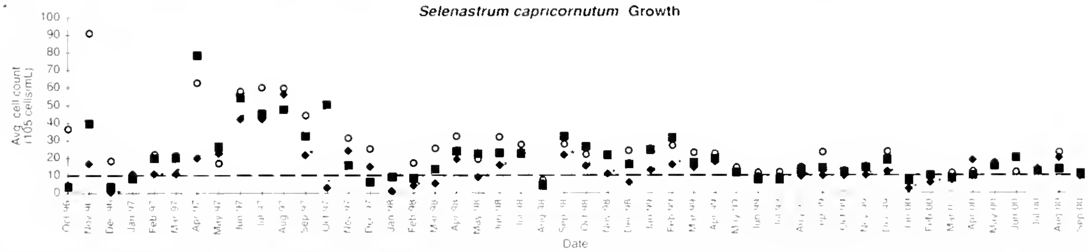


Figure 4
Station B Compared to Delta Mendota Canal—Acute Endpoints

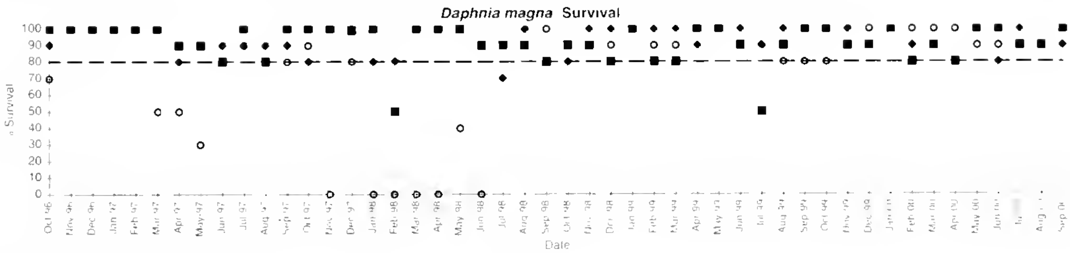
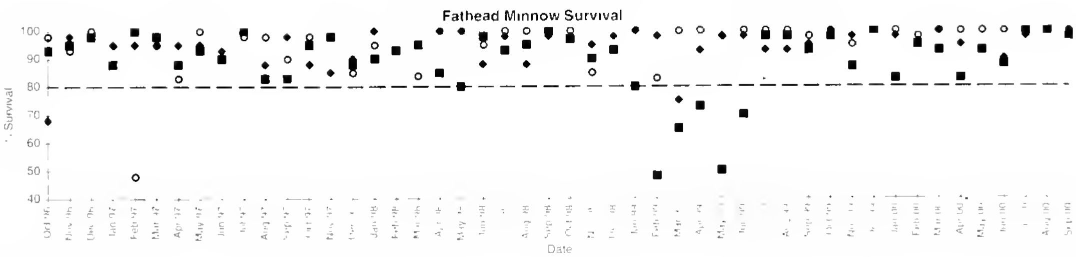


Figure 5
Station B Compared to Delta Mendota Canal—Acute Endpoints



■ Delta Mendota Canal (control)
◆ Station B
* Results statistically different from control
○ Laboratory Control
Minimum test acceptability for control

There were twelve monthly laboratory toxicity screening test periods between October 1999 and September 2000. Water samples were collected from Stations B, C, D, and F. DMC water is the ambient control water.

The USEPA Region IX laboratory performed concurrent toxicity tests with the BES laboratory from split samples collected during the April (fathead minnow and alga) sampling events.

The *D. magna* toxicity test survival results are presented in Table 1 and in Figures 4, 9, 14, and 19. There were no statistically significant ($p<0.05$) reductions in survival of *D. magna* during any of the testing events. This trend continues from the three previous water years.

There were no split sample comparisons available with *D. magna* with the USEPA Region IX laboratory.

All of the twelve concurrent *D. magna* reference toxicant survival endpoints were within the control chart limitations.

The DMC ambient control data met the 80% minimum survival acceptability criterion for all sampling

Table 1
Daphnia magna* Survival (Percent)

DATE	STATION					
	B	C	D	F	Ambient (DMC)	Laboratory Control
Oct-1999	100	100	100	100	100	80
Nov-1999	100	100	100	100	90	100
Dec-1999	90	100	100	100	90	100
Jan-2000	100	100	100	100	100	100
Feb-2000	90	90	70	70	80	100
Mar-2000	90	90	90	90	90	100
Apr-2000	80	100	90	90	80	100
May-2000	100	100	100	100	100	90
Jun-2000	80	100	100	90	100	90
Jul-2000	100	100	100	100	90	90
Aug-2000	90	100	90	100	90	90
Sep-2000	90	90	90	100	100	100

* Statistically significant event (P=0.05) Statistics were computed between all site means and the DMC ambient water sample. No statistics were computed between sampling dates

** DMC water failed to meet the survival (≥ 80%) acceptability criteria

Table 2
***Daphnia magna* Mean Reproduction**
(Number of Neonates per Female + Standard Deviation)

DATE	STATION					
	B	C	D	F	Ambient (DMC)	Laboratory Control
Oct-1999	31.7 + 12.3	25.7 + 6.9	28.4 + 12.1	22.2 + 10.0	22.8** + 6.2	16.8** + 4.9
Nov-1999	16.2 + 14.9	11.7 + 7.0	10.1 + 9.7	14.8 + 11.3	5.3 + 6.1	7.3 + 7.2
Dec-1999	34.9 + 8.0	32.0 + 7.5	43.0 + 6.9	37.7 + 3.5	31.2 + 12.1	40.9 + 5.3
Jan-2000	18.9 + 10.9	22.3 + 11.5	23.0 + 8.4	24.9 + 8.6	15.0 + 11.6	14.0 + 8.8
Feb-2000	37.1 + 10.9	29.0 + 14.6	24.5 + 19.6	22.7 +15.3	22.5 + 15.1	32.1 + 13.7
Mar-2000	18.6 + 10.6	29.3 + 10.6	25.4 + 13.0	22.7 + 10.6	11.0 + 6.2	20 + 12.7
Apr-2000	14.5 + 9.6	17.3 + 7.5	11.2 + 5.7	10.5 + 6.3	9.7** + 7.0	11.6 + 6.6
May-2000	13.4 + 3.5	18.5 + 7.4	12.5 + 5.4	9.7 + 5.0	11.4 + 6.2	17.7 + 5.6
Jun-2000	21.5 + 10.2	29.1 + 12.5	35.0 + 14.4	22.1 + 9.2	15.5 + 13.3	16.6 + 8.6
Jul-2000	27.3 + 12.0	36.8 + 9.7	31.4 + 6.9	17.0 + 6.1	8.8 + 3.7	28.6 + 12.3
Aug-2000	20.9 + 9.6	18.2 + 5.1	21.5 + 12.2	26.8 + 6.7	16.3 + 7.3	14.5 + 8.2
Sep-2000	42.4 + 18.2	38.9 + 19.6	19.9 + 18.1	41.6 + 8.0	48.7 + 15.6	31.8 + 4.6

* Statistically significant event (P=0.05) Statistics were computed between all site means and the DMC ambient water sample. No statistics were computed between sampling dates

** DMC water failed to meet the reproduction (≥ 10) acceptability criteria

events. The laboratory control met the survival acceptability criterion in all of the twelve test periods.

No adverse effects or specific trends were noted on *D. magna* survival during the fourth year of the GBP study, which is similar to the results from the first, second and third year of the GBP toxicity testing.

The *D. magna* reproduction results are presented in Table 2 and in Figures 1, 6, 11, and 16. None of the sampling events tests indicated statistically significant ($p<0.05$) reduced reproduction for water year (WY) 2000. In previous years, reduced reproduction was observed during the WY 1998 (December 1997 and January 1998, Stations B, D and F) and WY 1999 (October 1998, Stations B and D) testing periods.

No split sample comparisons were made with the USEPA Region IX laboratory.

All of the concurrent *D. magna* reference toxicant reproduction endpoints were within the control chart limitations.

The DMC ambient control data met the 10 neonates/surviving female minimum reproduction acceptability criterion in all but four test periods (November, 1999, March, May and July 2000). The laboratory control met the reproduction acceptability criterion in all but one of the twelve test periods (November, 1999).

No adverse effects or specific trends to the site waters were noted in *D. magna* reproduction during the fourth year of the GBP study.

The fathead minnow toxicity test survival results are presented in Table 3 and in Figures 5, 10, 15, and 20. Five sampling events showed statistically significantly ($p<0.05$) reduced fathead minnow larval survival results when compared to the DMC ambient control water. The reduced survival was observed in eleven tests during the October (Station F), November (Stations C, D, and F), December 1999 (Stations C, D, and F), January (Stations C and D) and February (Stations D and F) sampling events. The later months are generally the wet weather months.

April 2000 split sample comparisons with the USEPA Region IX laboratory showed similar results for all stations sampled and ambient water. Neither the BES data or the EPA data indicated statistical differences compared with the DMC water. The USEPA fathead minnow toxicity test results are presented in Table 11.

Each concurrent *P. promelas* reference toxicant survival endpoint was within the control chart limits.

Data for the DMC ambient control and the laboratory control meet the minimum 80% acceptability criteria.

The survival data for the fathead minnow larvae indicate an adverse effect for Stations C, D, and F from October through January. Stations D and F exhibited the greatest effects in total number of occurrences (4 sampling events). In the second and third years (1997-98, 1998-99) of the study, a generally similar trend was observed at the same stations always during the winter months. However, the second year of the study showed adverse effects at Stations C in seven sampling events while the third year of the study showed adverse effects in three sampling events. As in the previous year, adverse effects occurred in wet weather at Stations C, D and F. It should be noted that Stations C and F are out of the influence of Station B. Station D is influenced by both Station C and B water.

The fathead minnow toxicity test growth results are presented in Table 4 and in Figures 2, 7, 12, and 17. Statistically significantly reduced ($p<0.05$) growth rates were observed during the November (Stations C, D, and F), December (Stations C and F), January (Station C), and February (Station F) sampling events for a total of seven tests.

The April 2000 split sample comparisons with the USEPA Region IX laboratory showed similar results for all stations. Fish growth data from BES were from 26 to 46 percent less than the EPA data in actual fish weight. This may be due to different suppliers used to acquire the larval fish by BES and EPA. No statistical difference was indicated for any of the stations for larval fish growth by either BES or EPA.

Each concurrent *P. promelas* reference toxicant growth endpoint was within the control chart limits.

All data for the DMC ambient control and the laboratory control met the 0.25mg/surviving adult minimum growth acceptability criterion as shown in Table 4.

Table 3
***Pimephales promelas* (Fathead Minnow)**
Larval Survival (Percent + Standard Deviation)

DATE	STATION B	C	D	F	Ambient (DMC)	Laboratory Control
Oct-1999	100 + 0	98 + 5.0	90 +20.0	70* + 14.1	98 + 5.0	100 + 0
Nov-1999	98 + 5.0	38* + 15.0	60* + 14.1	50* + 29.4	87 + 5.0	95 + 10.0
Dec-1999	100 + 0	73* + 22.2	73* + 23.6	70* + 18.3	100 + 0	100 + 0
Jan-2000	98 + 5.0	33* + 18.9	48* + 27.5	85 +12.9	83 +12.6	100 + 0
Feb-2000	95 +5.8	85 + 17.3	65* + 12.9	75* + 10.0	95 + 10.0	98 + 5.0
Mar-2000	100 + 0	100 + 0	92.5 + 15	85 + 5.8	92.5 +9.6	100 + 0
Apr-2000	95 + 5.8	93 + 9.6	95 + 10.0	98 + 5.0	83 + 12.6	100 + 0
May-2000	93 + 9.6	93 + 9.6	98 + 5.0	100 + 0	93 + 15.0	100 + 0
Jun-2000	90 + 14.1	85 + 12.9	95 + 5.8	95 + 5.8	88 + 9.6	100 + 0
Jul-2000	98 + 5.0	100 + 0	90 + 20.0	98 + 5.0	100 + 0	100 + 0
Aug-2000	100 + 0	97 + 5.8	88 + 18.9	80 + 26.5	100 + 0	100 + 0
Sep-2000	100 + 0	100 + 0	93 + 5.0	98 + 5.0	98 + 5.0	98 + 5.0

* Statistically significant event (P=0.05). Statistics were computed between all site means and the DMC ambient water sample. No statistics were computed between sampling dates.
** Not a statistically significant event due to high variability in the response
*** DMC water failed to meet the survival (≥ 80%) acceptability criteria

Table 4
***Pimephales promelas* (Fathead Minnow) Mean Growth**
(In Milligrams + Standard Deviation)

DATE	STATION B	C	D	F	Ambient (DMC)	Laboratory Control
Oct-1999	0.7 + 0.05	0.62 +0.07	0.58 + 0.17	0.51 + 0.11	0.63 + 0.08	0.65 + 0.06
Nov-1999	0.58 + 0.08	0.20* + 0.11	0.35* + 0.06	0.29* + 0.18	0.42 + 0.19	0.52 + 0.07
Dec-1999	0.67 + 0.08	0.47* + 0.19	0.49 + 0.21	0.50* + 0.13	0.68 + 0.04	0.61 + 0.05
Jan-2000	0.68 +0.05	0.23* +0.16	0.37 + 0.19	0.59 + 0.08	0.53 + 0.13	0.64 +0.07
Feb-2000	0.71 + 0.07	0.60 + 0.18	0.54 + 0.16	0.51* + 0.09	0.68 + 0.13	0.65 + 0.07
Mar-2000	0.66 + 0.09	0.64 + 0.15	0.62 + 0.03	0.62 + 0.08	0.53 + 0.04	0.60 +0.11
Apr-2000	0.66 + 0.12	0.65 + 0.08	0.69 + 0.06	0.53 +0.09	0.51 + 0.09	0.82 + 0.06
May-2000	0.27 + 0.02	0.28 + 0.02	0.36 + 0.06	0.35 + 0.06	0.27 + 0.08	0.33 +0.04
Jun-2000	0.48 + 0.07	0.42 + 0.13	0.56 + 0.03	0.48 + 0.05	0.46 + 0.07	0.54 + 0.05
Jul-2000	0.68 + 0.16	0.60 + 0.04	0.58 + 0.15	0.62 + 0.04	0.62 + 0.05	0.68 + 0.04
Aug-2000	0.50 + 0.11	0.40 + 0.11	0.49 + 0.13	0.44 + 0.14	0.56 + 0.06	0.64 + 0.07
Sep-2000	0.42 + 0.04	0.34 + 0.05	0.34 + 0.02	0.41 + 0.01	0.37 + 0.02	0.34 + 0.02

* Statistically significant event (P=0.05). Statistics were computed between all site means and the DMC ambient water sample. No statistics were computed between sampling dates.
** Not a statistically significant event due to high variability in the response

The growth data for the fathead minnow larvae indicate an adverse effect for Stations C (3 sampling events), D (1 sampling event) and F (3 sampling events) during the winter months (November through February). The fish growth data follow trends similar to the fish survival data for WY 2000 with the exception of Station D, which had only one adverse event in November with respect to fish growth but four adverse events (November through February) with respect to survival. This implies for Station D that although fish survival was impacted for three consecutive sampling events, there was no observed adverse effect on growth at this Station during these same sampling events. For comparison, fish growth data for WY 1997 (3 sampling events) shows adverse effects on fish growth, in WY 1998, 14 sampling events indicated adverse effect on fish growth, in WY 1999, 6 sampling events indicated adverse growth effects and in WY 2000, 7 sampling events indicated adverse effects on fish growth (Figures 7, 12 and 17).

Selenastrum capricornutum 96-Hour Growth Test

The algal growth toxicity test results are presented in Table 5 and in Figures 3, 8, 13, and 18. Seven tests during 5 of the 12 sampling events produced statistically significantly reduced ($p<0.05$) algal growth. The reduced growth was observed during the October 1999 (Station D), November (Stations B and D), December (Station B) January (Station B), and February (Stations B and F)

Table 5
***Selenastrum capricornutum* Cell Counts (cells/mL) with Variance (%)**
Cell count values expressed as the exponent 10^5.
(Selenate added)

DATE	STATION											
	B	Var. (%)	C	Var. (%)	D	Var. (%)	F	Var. (%)	Ambient (DMC)	Var. (%)	Lab Control	Var. (%)
Oct-1999	9.8	7.6	10.7	22.1	9.0*	7.4	11.4	9.9	11.8	17.1	12.7	15.3
Nov-1999	9.9*	6.1	12.8	10.5	11.4*	4.2	12.9	9.2	14.3	6.1	15.3	9.7
Dec-1999	12*	6.3	22.7	8.0	20.9	16.4	20.4	7.0	18.8	12.5	23.4	5.2
Jan-2000	2.3*	9.4	6.5	15.6	7.5	6.1	7.3	8.3	6.9**	17.6	8.2**	4.7
Feb-2000	5.8*	28.0	9.4	6.5	9.8	15.6	6.7*	17.0	10.0	9.7	10.2	22.6
Mar-2000	7.1	39.1	9.7	23.5	8.0	26.7	8.1	32.6	8.31***	24.2	11.4***	21.8
Apr-2000	18.7	9.3	19.9	8.9	21.5	17.0	22.4	6.4	10.0	19.6	12.2	11.5
May-2000	16.2	12.2	16.3	6.9	17.3	8.2	16.5	5.3	15.2	28.2	17.2	15.8
Jun-2000	19.7	1.3	24.3	3.1	21.7	0.6	21.4	6.3	19.9	3.6	11.9	0.8
Jul-2000	13.7	10.9	16.3	38.7	13.5	11.1	11.3	38.0	12.1	19.9	13.3	23.7
Aug-2000	19.8	18.0	25.1	7.3	24.8	8.9	33.3	13.4	13.4	16.2	23.0	15.8
Sep-2000	9.4	7.0	11.5	6.1	10.8	11.4	13.7	21.7	10.8	9.6	9.6	11.7

* Statistically significant event (P=0.05) Statistics were computed between all site means and the DMC ambient water sample. No statistics were computed between sampling dates.
** DMC/Control water failed to meet the growth ($\geq 1 \times 10^6$) acceptability criteria.
*** DMC/Control water failed to meet the variance ($\leq$ 20%) acceptability criteria.

testing periods. As indicated, 4 of the 6 samples were collected at Station B (with reduced algal growth). Definitive bioassays were completed on Station B samples for all months of WY 2000 except October. The results as shown in Table 12 indicate NOECs greater than 100 percent for March through May, July and August. The December 1999 and September NOECs were less than 6.25 percent. The September data implied an interrupted dose response for Station B growth, indicating action by two different toxicants. That is, one toxicant may effect organisms at lower concentrations and the other toxicant may effect organisms at a greater concentration. A dose response could not be calculated for the September 2000 data.

April split sample results with the USEPA Region IX laboratory were similar (Table 11). However, the BES cell counts were about 30 to 38 percent lower. This may be due to the different methods used to count cells: BES uses a Coulter Counter, the EPA laboratory uses a hemocytometer. Differences of these two counting methods have been documented by BES during a study conducted during 1999.

Each of the concurrent *S. capricornutum* reference toxicant growth endpoints were within the control chart limit. However, the variability exceeded the suggested 20% acceptability criterion in 2 out of the 12 tests in March for both the DMC and laboratory control water. Three of the 12 DMC ambient control samples failed to meet the growth ($\geq 1\text{x } 10^6$) acceptability criteria in January, March and April sampling events.

The ambient and laboratory control met the minimum algal cell density on all but two sampling events (January and March 2000). Therefore data for these two months were not valid. These results are summarized in Table 5.

This is the fourth year that *S. capricornutum* tests have shown reduced growth in Stations B, D and F.

Water Chemistry

Selenium

The selenium data are presented in Table 1a and Figure 21. The highest selenium concentrations (>80 mg/L) were detected at Station B during the March, April, and May 2000 sampling events. The October 1999 and August 2000 sampling events had the lowest selenium concentrations of 23 to 24 mg/L. These data are consistent with selenium concentrations during the preceding water year as indicated in Table 13. Algal cell-count reduction was observed during the months of November 1999 through February 2000 for Station B. The same trend was observed during the preceding water year. Significant algal cell-count reductions were observed during March and April in WY 1997 and the March and May sampling events of WY 1998 at Station B (Figure 3). Based on these data as in the preceding years, it

Figure 6
Station C Compared to Delta Mendota Canal—Chronic Endpoints

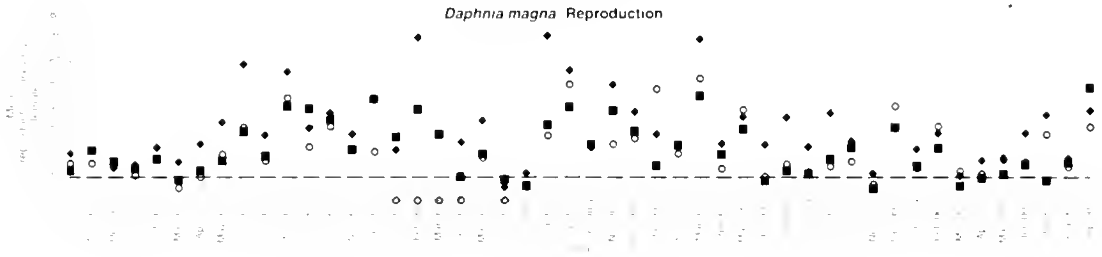


Figure 7
Station C Compared to Delta Mendota Canal—Chronic Endpoints

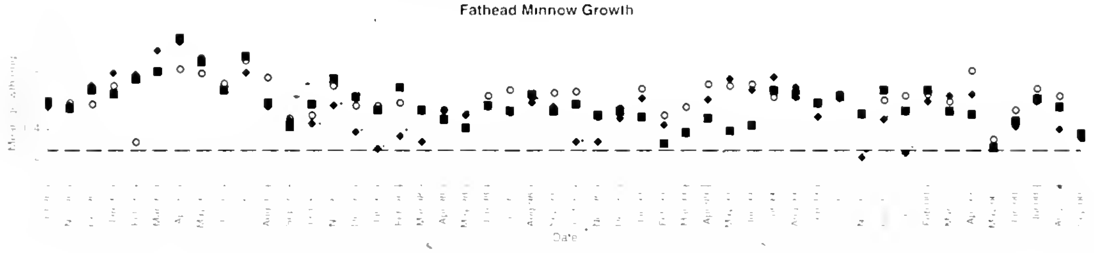


Figure 8
Station C Compared to Delta Mendota Canal—Chronic Endpoints

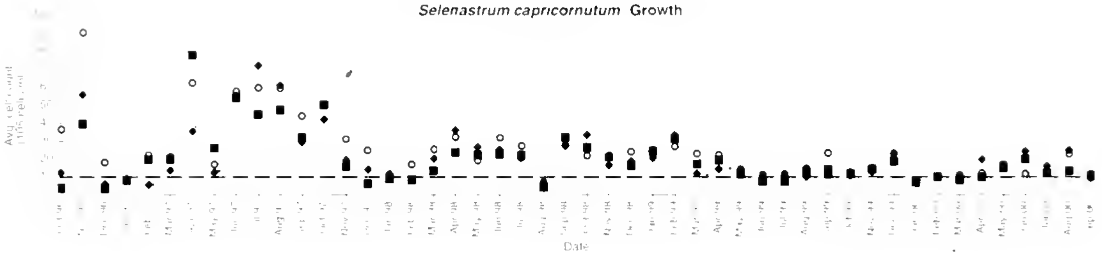


Figure 9
Station C Compared to Delta Mendota Canal—Acute Endpoints

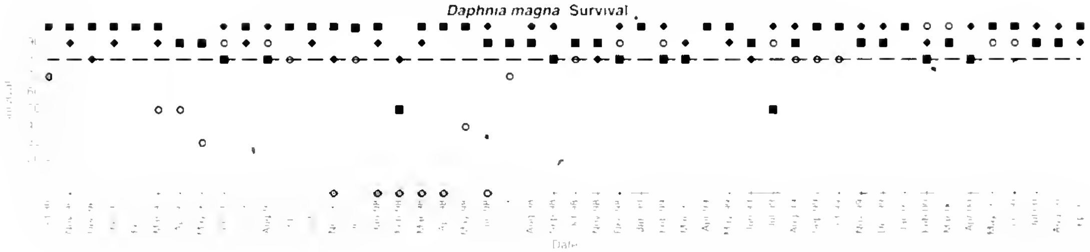


Figure 10
Station C Compared to Delta Mendota Canal—Acute Endpoints

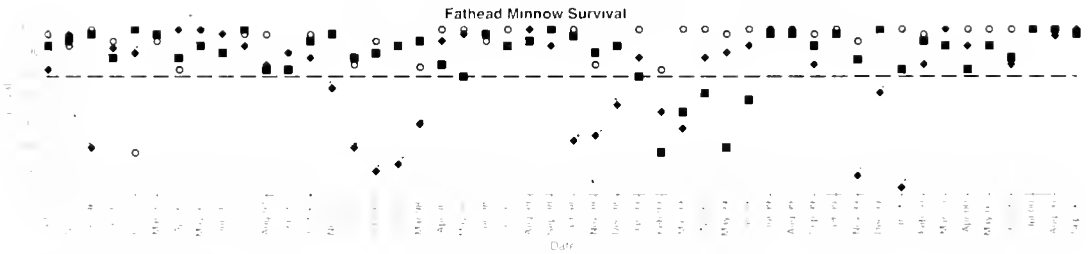


Figure 11
Station D Compared to Delta Mendota Canal—Chronic Endpoints

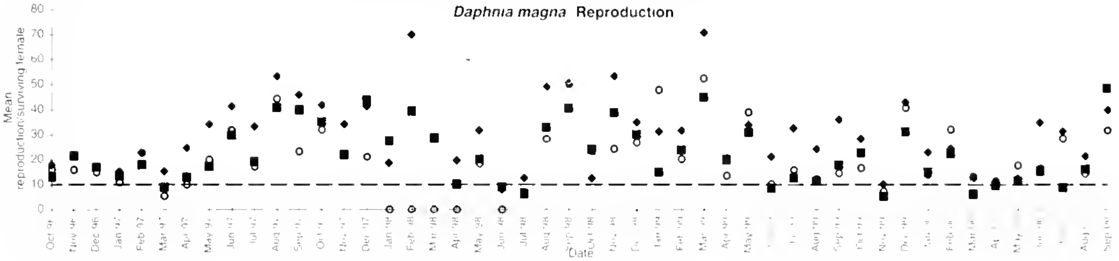


Figure 12
Station D Compared to Delta Mendota Canal—Chronic Endpoints

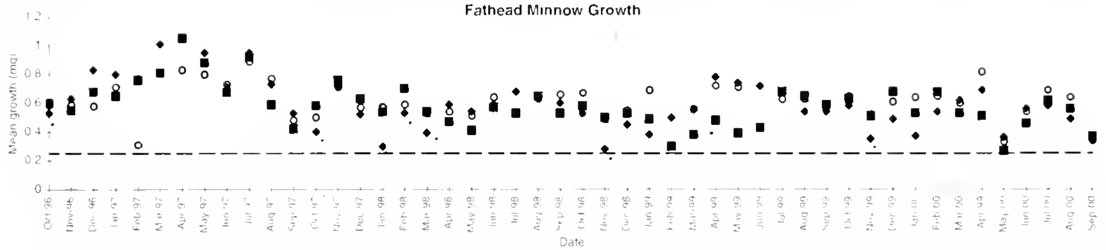


Figure 13
Station D Compared to Delta Mendota Canal—Chronic Endpoints

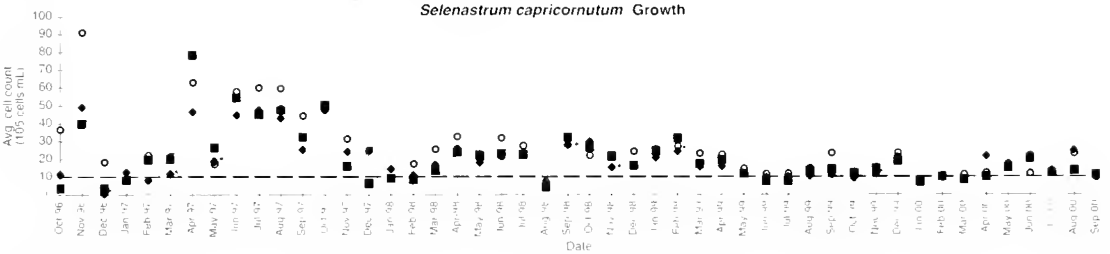


Figure 14
Station D Compared to Delta Mendota Canal—Acute Endpoints

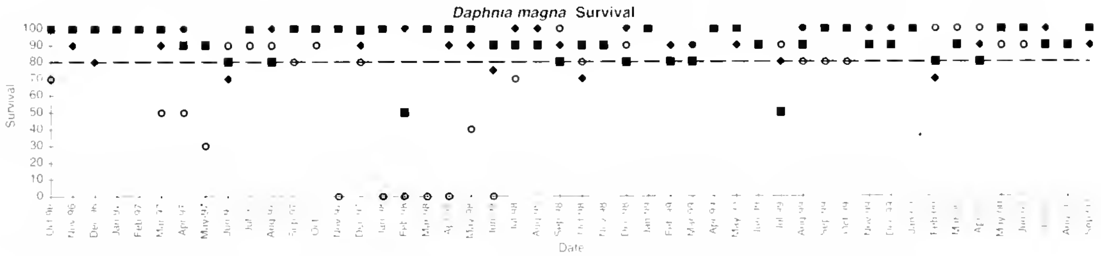
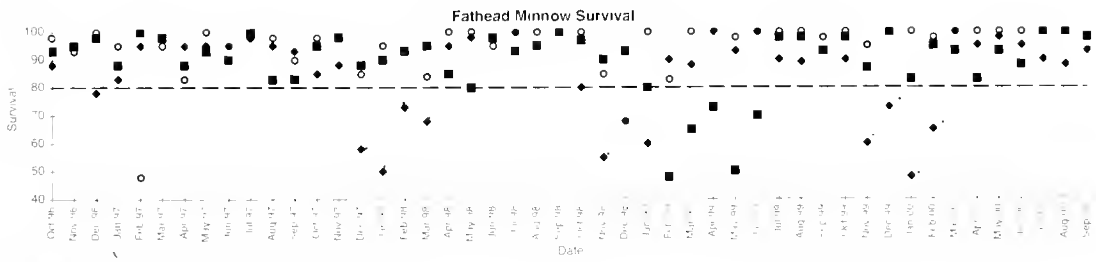


Figure 15
Station D Compared to Delta Mendota Canal—Acute Endpoints



■ Delta Mendota Canal (control)
◆ Station D
* Results statistically different from control
○ Laboratory Control
- Minimum test acceptability for control

appears that no specific relationship can be made between reduced alga cell counts and selenium concentrations at Station B. That is, algal cell-count reduction is not observed at Station B when selenium concentrations were highest (March, April and May of WY 2000). It may well be that significant algal cell-count reductions in Station B waters are due to some chemical species other than selenium.

Station D selenium concentrations follow the same trends as Station B selenium concentrations but were typically 70 percent lower than Station B water during the October through April sampling events and approach the same concentrations as Station B for June through August for WY 2000.

The selenium concentrations for each site were similar to those measured by the Central Valley Regional Water Quality Control Board (see Chapter 4 of this report).

Sulfate

The sulfate results are presented in Figure 22 and Table A2. Sulfate concentrations followed similar trends as selenium concentrations for the same site. Station B had the highest concentrations of sulfate with peaks up to 1990 mg/L in May 2000. Higher concentrations of sulfate were also observed in May, October and November 1997, in May and June 1998 and April 1999 (Table 13). These elevated sulfate concentrations could not be related with increased toxicity in any of the organisms studied when data from Table A2 and 14 are compared with the toxicity data during the same sampling period.

Other Water Chemistry

The laboratory water chemistry data are presented in Figures 23–30 and Tables A3 through A12. All analyses were performed at the BES Laboratory, except for selenium and sulfate. Tables 6–9 provide water chemistry data collected in the field for conductivity, DO, pH, and temperature for the first day the sample set was collected.

The conductivity was higher for Station B water for all months, with Station C and F having the lowest conductivity. The DO and pH of all stations were similar, with Station F showing the lowest pH except during April, when pH was similar to other stations. The Station B water is about three times greater in hardness than the other stations, exceeding 1000 mg/L (as $CaCO_3$) during October 1999 through January 2000. Total suspended solids were generally higher in Station C and F water and lowest in Station B water. Suspended solids remain higher from February through September at Stations C, D and F. No trend in alkalinity was observed except that Station F is lower than the other stations sampled. The highest ammonia nitrogen concentration was observed in May 2000 at Station B (5.50 mg/L). The total chlorine concentration ranged from nondetectable to 0.3 mg/L for all stations sampled. Station B water has indicated higher hardness levels than at the other stations studied in the biomonitoring program.

Conclusions

A total of 144 laboratory toxicity screening tests (four sites, 12 months with three species) comparing the station waters (B, C, D, and F) with the ambient control (Delta Mendota Canal) were conducted between October 1999 and September 2000 using three species short-term chronic tests. Each set of tests included five toxicity endpoints (fish survival and growth, water flea survival and reproduction, and algae growth). Of these tests, 25 endpoints of the 240 possible (10 %) exhibited statistically significantly reduced endpoints ($P<0.05$) compared to the ambient control tests (Station B = 4, Station C = 6, Station D = 7, and Station F = 8). This level of significantly reduced endpoints represents a decrease from the previous year (WY 1999) of 28 significantly reduced endpoints and 40 significantly reduced endpoints for WY 1998 of the total 240 toxic endpoints evaluated. The *Daphnia magna* was the least sensitive of the species tested accounting for no significant responses during WY 2000, two responses for WY 1999 and 4 responses in WY 1998 using both survival and reproduction as the endpoints.

For the fourth year the algae exposed to Station B water exhibited reduced growth when compared to DMC ambient control water in four out of twelve months. This is less than the six responses noted in WY 1999. The algae were responsible for 7 of the 25 statistically significant endpoints using cell growth as an endpoint. Definitive testing had been initiated for Station B to evaluate the no observed effect concentration (NOEC) for Station B test water when compared to ambient water. The definitive testing was initiated in November 1999. Of the 11 samples in which definitive testing was completed, five samples showed NOECs greater than 100, one sample had an NOEC at 50 percent (November 1999), two samples at 25 percent (January and February 2000), one sampled at 12.5 percent (June 2000), and two samples (December 1999 and September 2000) with NOECs less than 6.5

Table 6

Conductivity (µS) of Water Measured in the Field, Day 1

MONTH	STATION B	C	D	F	Ambient
Oct-1999	4300	816	1693	1171	528
Nov-1999	3960	987	1749	1146	587
Dec-1999	4200	1670	2120	1920	651
Jan-2000	4590	1383	2240	2020	535
Feb-2000	999	999	999	560	697
Mar-2000	4800	1896	2920	1609	386
Apr-2000	4910	2020	3490	1297	273
May-2000	2405	1520	2088	1051	268
Jun-2000	930	347	798	248	73
Jul-2000	3900	1500	3400	1100	2280
Aug-2000	2600	1372	2000	933	282
Sep-2000	3180	520	2290	810	300

Table 7

Dissolved Oxygen (in mg/L) of Water Measured in the Field, Day 1

MONTH	STATION B	C	D	F	Ambient
Oct-1999	11.2	4.7	5.0	7.2	6.9
Nov-1999	12.3	7.9	8.1	8.8	9.7
Dec-1999	18.3	15.3	14.9	13.5	16.4
Jan-2000	12.5	10.6	12.0	9.2	10.0
Feb-2000	11.7	9.3	10.7	8.1	11.7
Mar-2000	14.2	12.3	11.7	9.1	14.2
Apr-2000	12.8	8.5	10.6	8.2	10.5
May-2000	16.2	12.6	12.0	19.3	12.3
Jun-2000	11.9	12.3	13.0	14.0	12.0
Jul-2000	11.4	12.2	12.8	16.4	13.5
Aug-2000	11.5	12.8	16.5	16.0	11.2
Sep-2000	6.4	6.2	6.7	6.1	6.2

Table 8

pH of Water Measured in the Field, Day 1

MONTH	STATION B	C	D	F	Ambient
Oct-1999	8.4	NA	8.0	NA	8.1
Nov-1999	8.4	8.2	8.2	8.0	8.2
Dec-1999	8.4	8.3	8.3	8.0	8.2
Jan-2000	8.1	8.2	8.2	7.7	7.8
Feb-2000	7.9	7.9	7.7	7.3	7.6
Mar-2000	8.9	8.7	8.7	8.8	8.3
Apr-2000	8.9	8.8	9.0	8.1	9.0
May-2000	8.5	8.1	8.4	7.7	8.4
Jun-2000	8.4	8.3	8.4	7.8	8.0
Jul-2000	8.6	8.0	8.5	7.8	8.0
Aug-2000	9.0	8.9	9.9	8.0	9.3
Sep-2000	8.5	8.5	8.5	7.8	8.4

NA - Not Available

Figure 16
Station F Compared to Delta Mendota Canal—Chronic Endpoints

Daphnia magna Reproduction

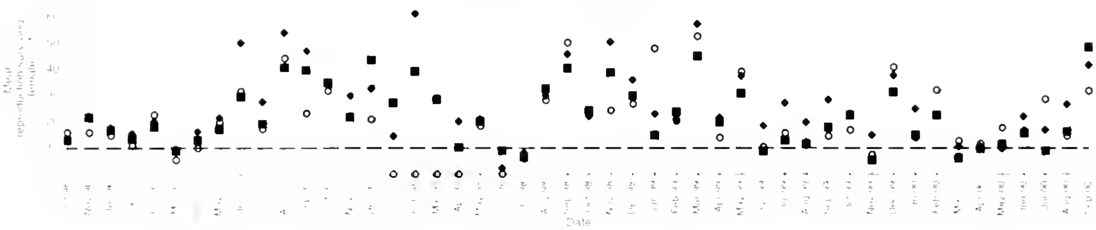


Figure 17
Station F Compared to Delta Mendota Canal—Chronic Endpoints

Fathead Minnow Growth

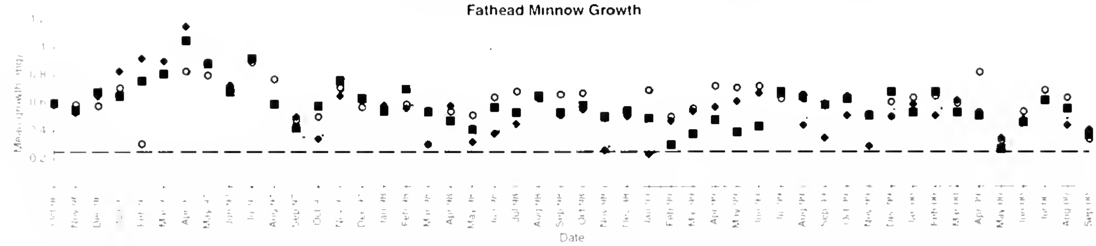


Figure 18
Station F Compared to Delta Mendota Canal—Chronic Endpoints

Selenastrum capricornutum Growth

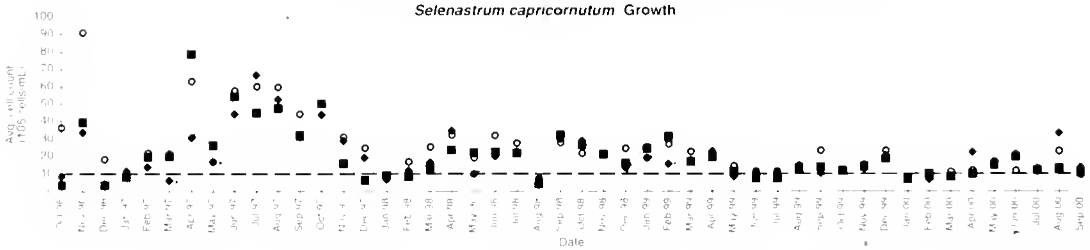


Figure 19
Station F Compared to Delta Mendota Canal—Acute Endpoints

Daphnia magna Survival

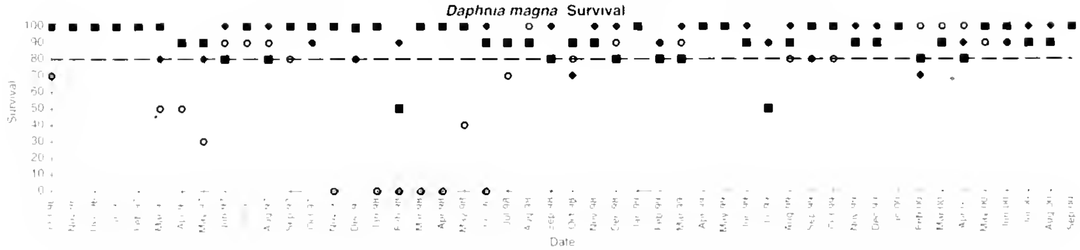
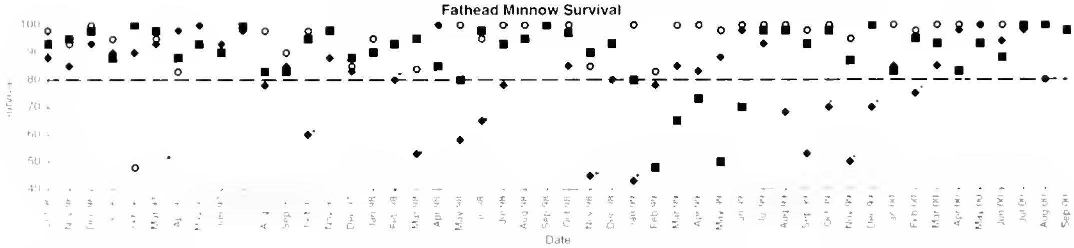


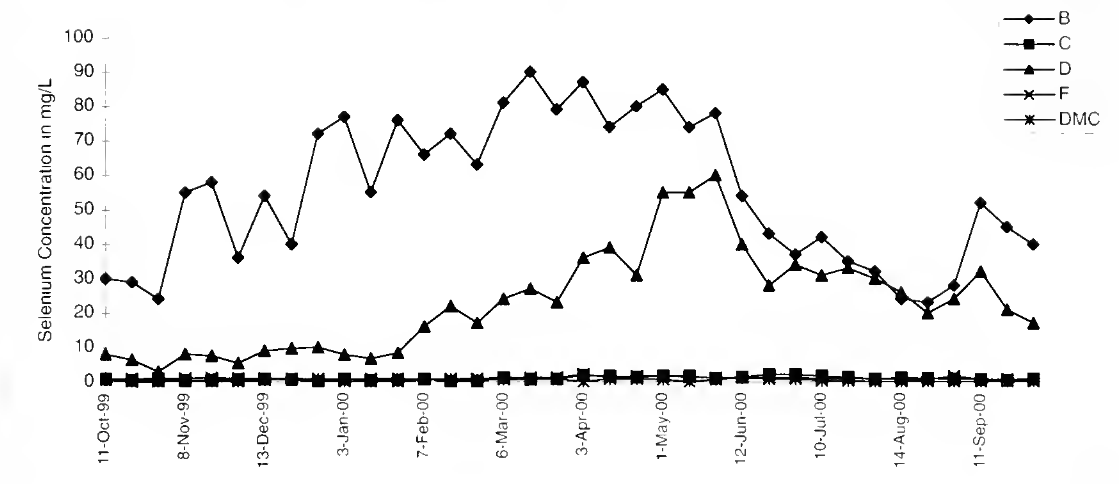
Figure 20
Station F Compared to Delta Mendota Canal—Acute Endpoints

Fathead Minnow Survival



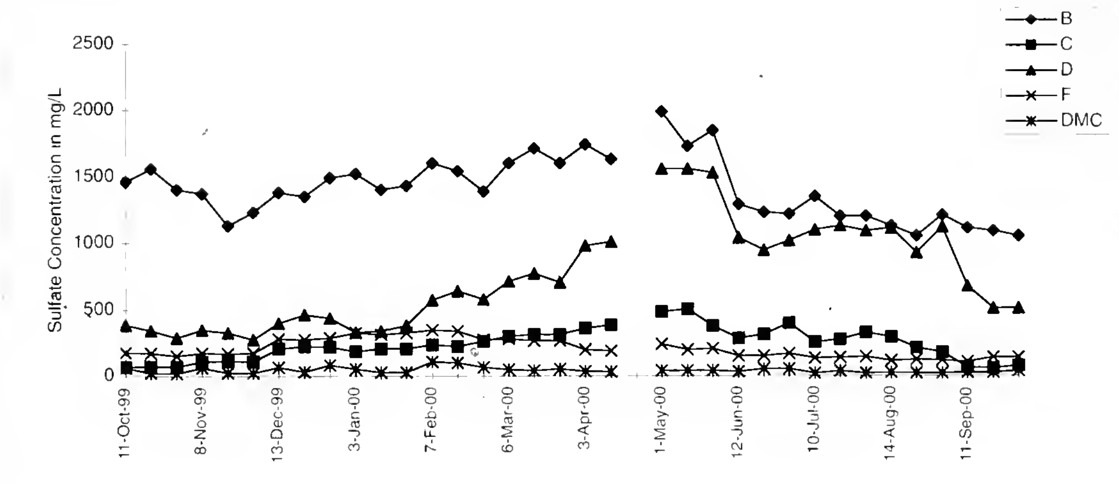
● Delta Mendota Canal Control
◆ Station F
Results statistically different from control
Laboratory Control
Minimum test acceptability for control

Figure 21
Selenium of Water Measured by USBR



Detection limit 0 40 µg/L for all tests

Figure 22
Sulfate of Water Measured by USBR



Data for April 7 not available

percent as shown Table 12. The latter two samples did not have an acceptable dose response curve. A comparison of data shown Figures 3 and 21 indicate that selenium concentrations found in the Station B water do not appear to be associated with the algal growth reductions.

The larval fathead minnow accounted for 18 of the significant responses using survival and growth as the endpoints. The majority of these responses were during the winter months (October 1999 through February 2000) at Stations C, D, and F. BES initiated a screening toxicity investigation evaluation (TIE) during the months of October and November, 1999. The TIE requires that the toxicity tests be repeated on chemically manipulated test water in order to determine the cause of toxicity. During the October and December TIE testing, there was a immediate loss of toxicity which did not allow for the completion of the TIE.

Figure 23
Conductivity of Water Measured at BES Laboratory

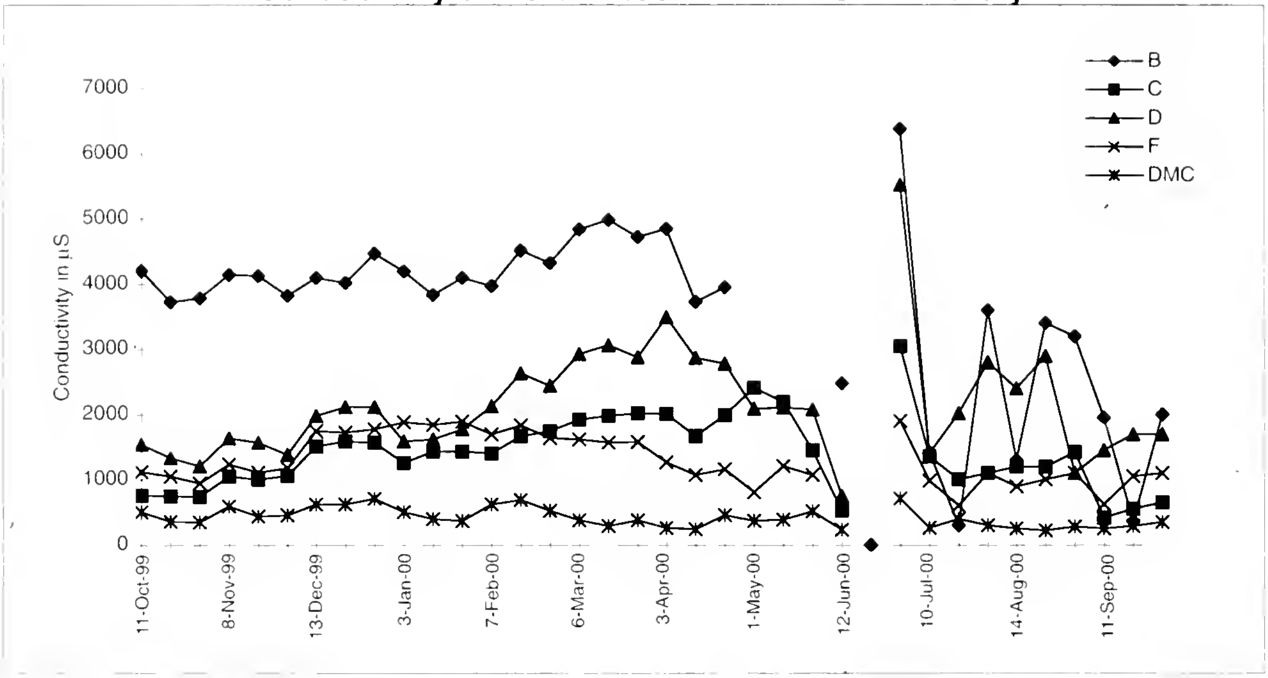


Figure 24
Total Suspended Solids of Water Measured at BES Laboratory

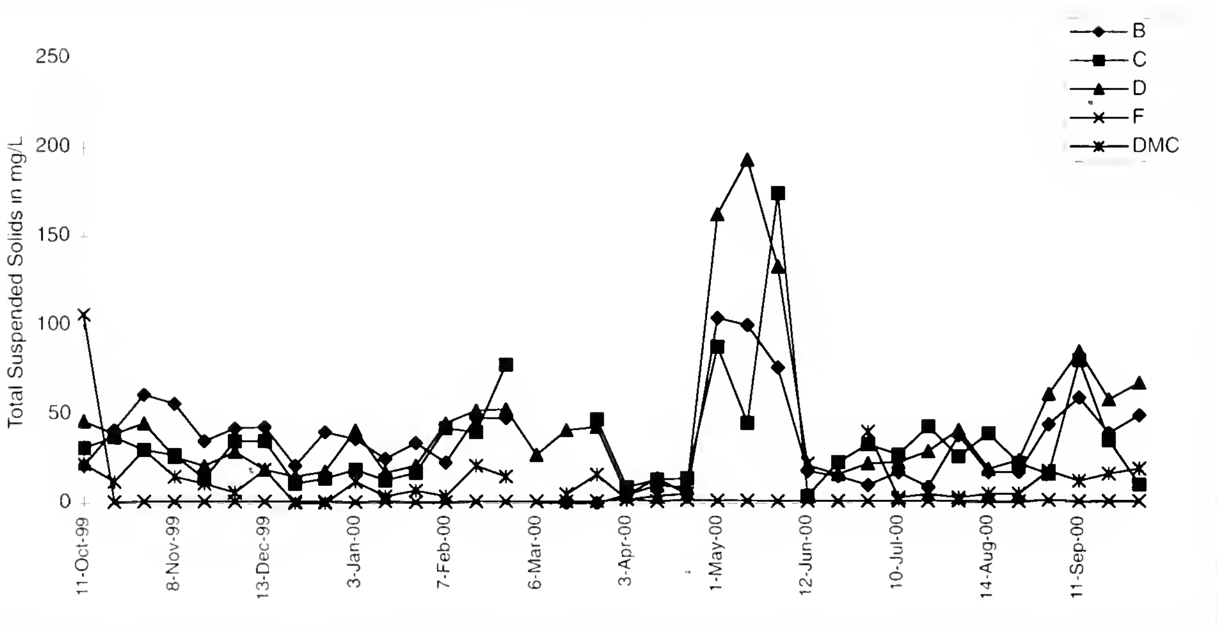


Figure 25
Dissolved Oxygen of Water Measured at the BES Laboratory

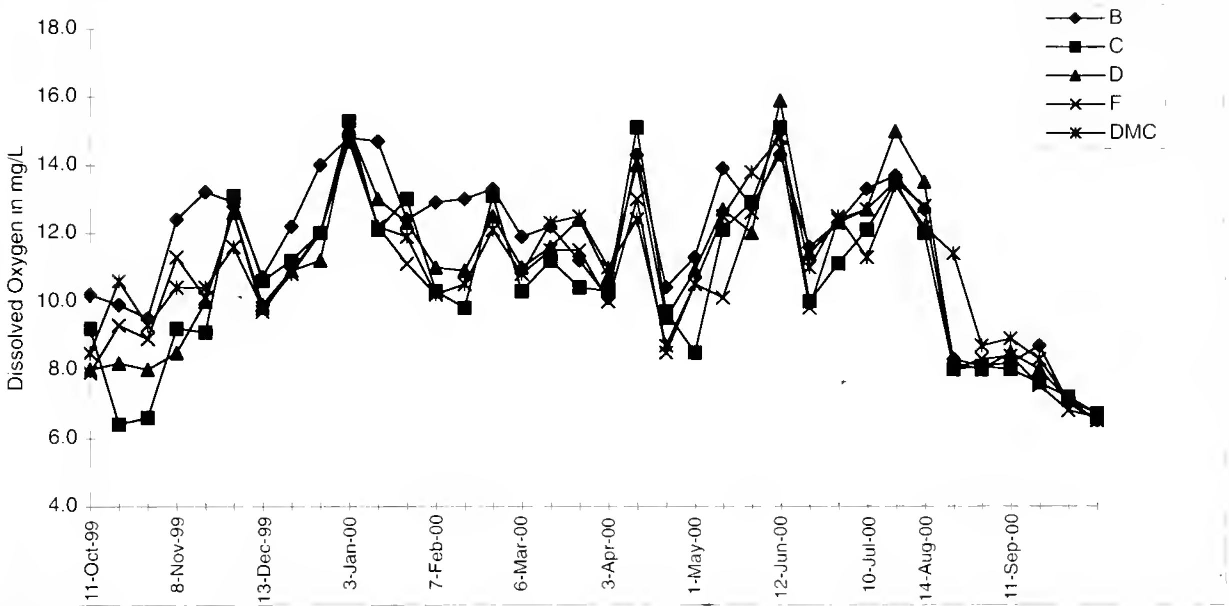


Figure 26
pH of Water Measured at the BES Laboratory

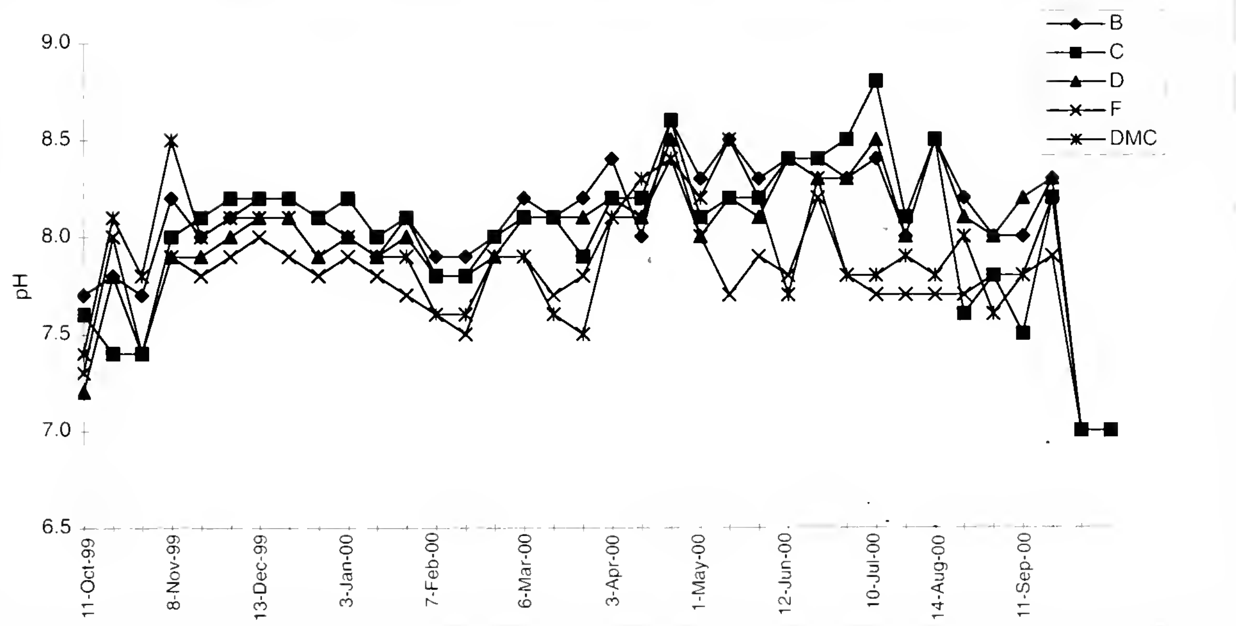
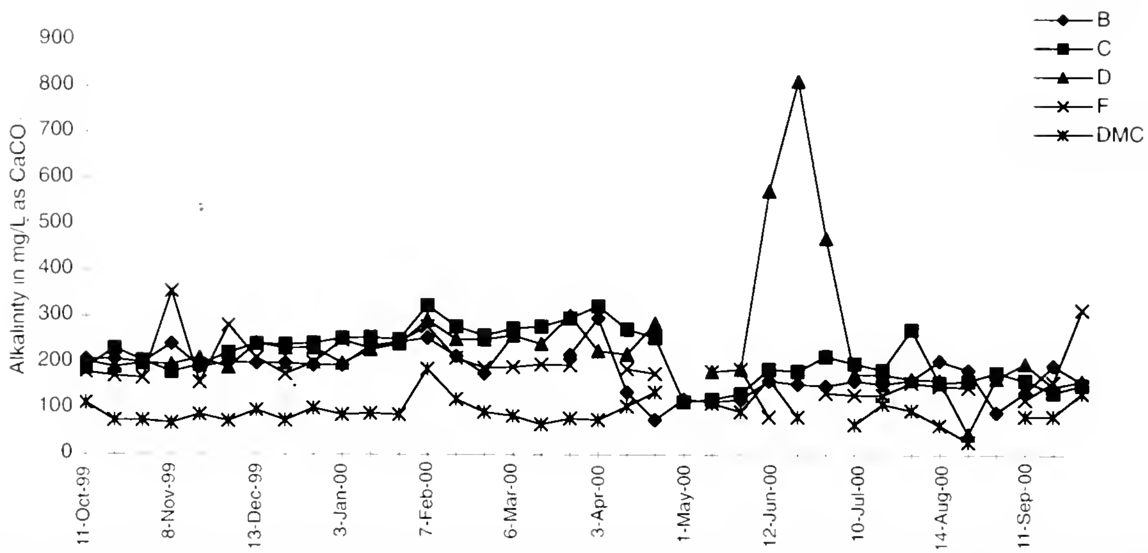


Figure 27
Alkalinity of Water Measured at the BES Laboratory



* Measurement Not Available (NA) for Site B

Figure 28
Hardness of Water Measured at the BES Laboratory

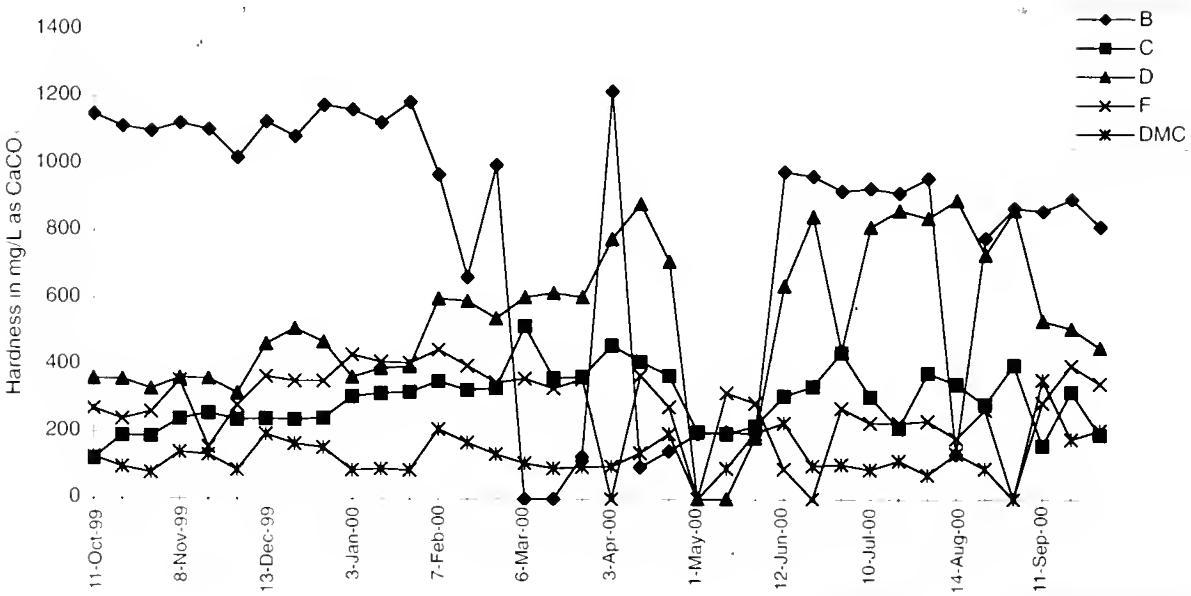


Figure 29
Ammonia of Water Measured at the BES Laboratory

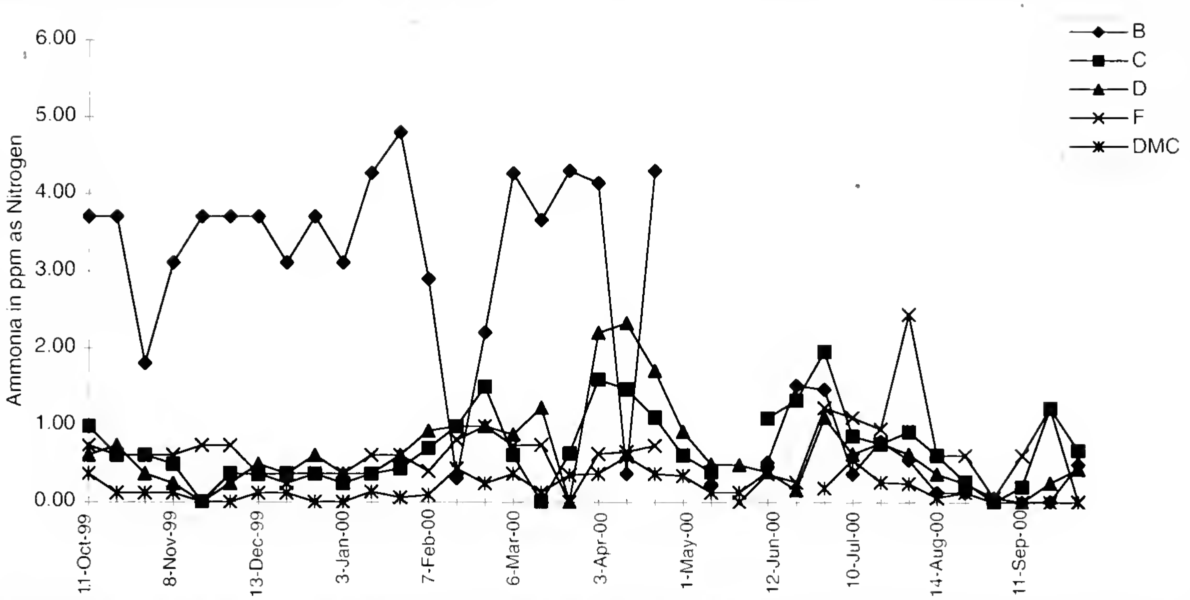
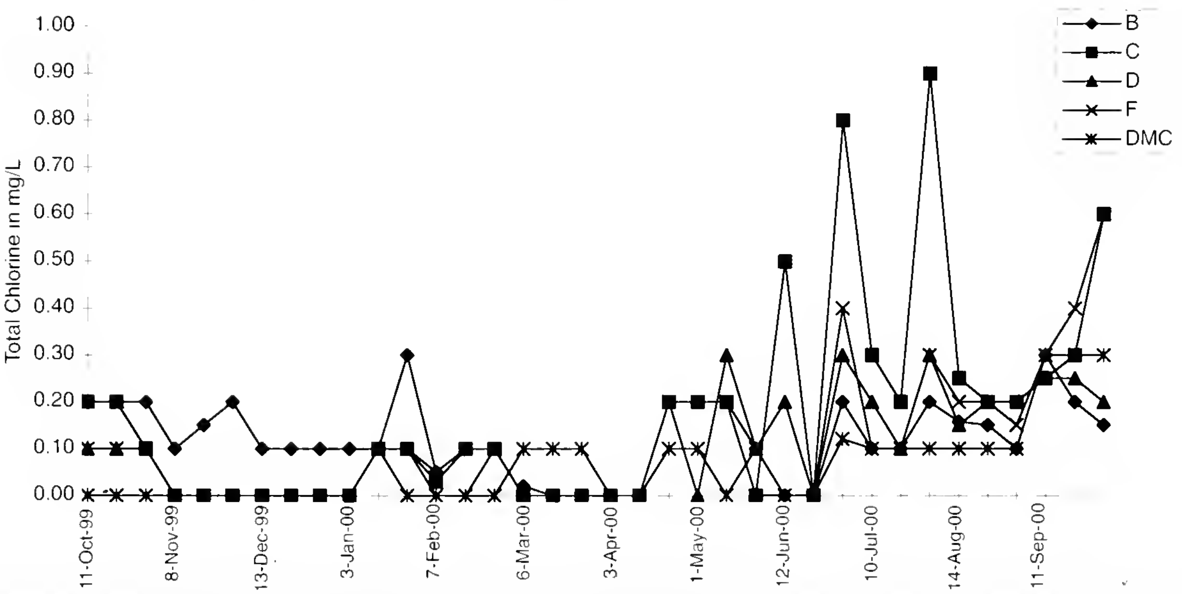


Figure 30
Total Chlorine of Water Measured at the BES Laboratory



0.0 Corresponds to a non-detectable concentration (i.e. <0.1)

Table 9
Temperature (deg. Celsius) of Water Measured in the Field, Day 1

	STATION				
MONTH	B	C	D	F	Ambient
Oct-1999	22.8	22.8	22.3	20.8	21.1
Nov-1999	13.5	12.9	12.9	12.5	13.6
Dec-1999	7.2	7.2	7.2	7.8	7.5
Jan-2000	8.5	8.1	8.1	8.6	9.2
Feb-2000	NA	13.5	NA	10.0	11.4
Mar-2000	13.9	12.7	12.7	13.0	13.5
Apr-2000	19.7	19.5	19.5	19.0	18.6
May-2000	12.9	14.1	12.7	12.7	9.9
Jun-2000	24.0	26.0	24.0	23.0	22.0
Jul-2000	13.2	14.4	13.5	12.6	12.8
Aug-2000	26.0	24.3	26.0	24.2	25.0
Sep-2000	23.0	24.5	23.5	25.2	23.0

Table 10
Table 2B-5: Depth of Sample Point (in feet), Day 1

	STATION				
MONTH	B	C	D	F	Ambient
Oct-1999	6.5	5.5	5.7	8.5	16.0
Nov-1999	6.6	6.0	6.0	5.0	13.7
Dec-1999	6.5	5.5	5.5	5.5	6.0
Jan-2000	6.3	5.9	5.9	5.5	10.0
Feb-2000	5.8	5.5	6.8	6.0	15.0
Mar-2000	7.1	6.4	6.4	7.5	16.0
Apr-2000	6.5	6.5	5.1	4.5	15.9
May-2000	6.5	NA	NA	5.5	NA
Jun-2000	7.2	5.2	5.2	5.0	16.0
Jul-2000	NA	NA	NA	NA	NA
Aug-2000	7.0	4.5	4.5	5.0	16.0
Sep-2000	5.3	4.5	4.5	5.0	15.0

NA - Not Available

Table 11
U.S. EPA Toxicity Testing Data Summary - April 2000

Organism	Test	Station B	Station C	Station D	Station F	DMC	Lab Control
Fathead minnow	7day % survival	95%	98%	98%	85%	98%	98%
Fathead minnow	7 day growth (mg/fish)	0.92	0.98	1.03	0.91	0.87	0.75
*Selenastrum capricornutum***	Growth (10[illegible] cells/mL)	26.6	31.20	34.9	28.3	23.1	13.4

* Statistically significant

** Estimated from absorbance reading and the lab calibration curve. All other values are from microscopic cell counts

' Statististically significant compared to than lab control. Only Site Ambient was compared to lab control

Source: U.S. EPA Region IX Laboratory, *Grasslands Bypass Project Toxicity Testing Report*, June 1999

Table 12
Statistical Analysis of Growth Endpoint for Station B

Test Month	IC 50	IC 25	NOEC	LOEC	Toxic Units
Oct-1999	NA	NA	NA	NA	NA
Nov-1999	>100	87.45	50	100	2
Dec-1999	>100	54.44	<6.25	6.25	>16
Jan-2000	72.98	38.58	25	50	4
Feb-2000	>100	36.68	25	50	4
Mar-2000	>100	100	>100	>100	<1
Apr-2000	>100	>100	>100	>100	<1
May-2000	>100	>100	>100	>100	<1
Jun-2000	>100	>100	12.5	25	8
Jul-2000	>100	>100	>100	>100	<1
Aug-2000	>100	>100	>100	>100	<1
Sep-2000	NA	NA	<6.25	6.25	>16

NA - Not available

Table 13. Selenium ($\mu g/L$) as Measured by the Bureau of Reclamation

MONTH	SAMPLE DATE	STATION				
		B	C	D	F	DMC
Oct-1998	12-Oct	49	0.7	9.4	0.8	0
	14-Oct	37	0.6	8.1	1.1	0.4
	16-Oct	46	0.6	10	1	0
Nov-1998	10-Nov	47	0.6	7.8	1	0
	12-Nov	46	0.7	6.7	0.9	0.7
	14-Nov	52	0.6	8	0.9	0.5
Dec-1998	7-Dec	50	0.5	6.3	0.8	0.5
	9-Dec-	79	0.6	7.5	0.8	0.5
	11-Dec	56	0.5	8.7	0.8	0.6
Jan-1999	11-Jan	46	0.8	12	1.2	1
	13-Jan	50	0.9	9.8	1	1
	15-Jan	49	0.7	9.2	1	1.2
Feb-1999	8-Feb	57	0.7	11	1.1	0.6
	10-Feb	60	0.8	17	1	0.8
	12-Feb	66	0.8	11	1	0.6
Mar-1999	8-Mar	89	1.3	26	1.3	0.9
	10-Mar	80	0.9	25	1.1	1
	12-Mar	88	0.9	27	1.4	1.1
Apr-1999	5-Apr	94	1.2	45	1.2	1
	7-Apr	133	1.3	40	1.1	0.8
	9-Apr	88	1.4	36	1.5	0.7
May-1999	10-May	69	1.3	42	0.9	0.7
	12-May	67	1.4	30	1	0.5
	14-May	61	1	48	0.7	0.6
Jun-1999	14-Jun	44	1.2	34	1	0
	16-Jun	52	1.4	37	0.9	0
	18-Jun	54	1.4	43	0.7	0.5
Jul-1999	12-Jul	45	2.5	38	0.9	0
	14-Jul	38	1.9	28	0.9	0
	16-Jul	43	1.9	29	1	0
Aug-1999	9-Aug	23	1.8	13	0.8	0
	11-Aug	18	0.9	16	0.7	0
	13-Aug	24	1	21	0.9	0
Sep-1999	13-Sep	43	1.2	19	1.2	0.6
	15-Sep	34	0.9	23	1.1	0
	17-Sep	43	1	22	1.3	0

Table 14. Sulfate (mg/L) as Measured by the Bureau of Reclamation

MONTH	SAMPLE DATE	STATION B	C	D	F	DMC
Oct-1998	12-Oct	1390	71	317	115	15
	14-Oct	1630	69	287	108	17
	16-Oct	1660	77	373	112	25
Nov-1998	10-Nov	1510	126	342	148	18
	12-Nov	1470	131	322	160	48
	14-Nov	1560	139	318	161	35
Dec-1998	7-Dec	1710	176	374	205	44
	9-Dec	1690	186	389	225	50
	11-Dec	1440	193	343	226	53
Jan-1999	11-Jan	1520	276	499	200	69
	13-Jan	1480	274	469	205	77
	15-Jan	1500	267	442	208	97
Feb-1999	8-Feb	1350	269	482	260	47
	10-Feb	1410	272	586	231	45
	12-Feb	1380	215	403	259	56
Mar-1999	8-Mar	1860	286	734	229	40
	10-Mar	1730	296	716	246	43
	12-Mar	1840	322	778	234	51
Apr-1999	5-Apr	2010	423	1010	365	78
	7-Apr	2150	394	1010	363	67
	9-Apr	1920	355	875	275	78
May-1999	10-May	1720	345	1380	206	35
	12-May	1770	217	943	177	37
	14-May	1780	448	1480	265	38
Jun-1999	14-Jun	1500	414	1190	149	30
	16-Jun	1580	332	1120	164	32
	18-Jun	1600	417	1340	191	43
Jul-1999	12-Jul	1360	308	1190	128	24
	14-Jul	1370	245	1060	120	18
	16-Jul	1370	260	1060	135	18
Aug-1999	9-Aug	1170	230	1020	89	19
	11-Aug	1020	299	1110	62	16
	13-Aug	866	296	1230	130	12
Sep-1999	13-Sep	1430	104	638	112	48
	15-Sep	1370	74	843	115	22
	17-Sep	1520	77	758	114	28

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U.S. Environmental Protection Agency. 1987. A Short-term Chronic Toxicity Test Using Daphnia magna. EPA/600/D-87/080. March, 1987. Office of Research and Development.

TABLE A1: Selenium (μg/L) as Measured by the Bureau of Reclamation

MONTH	SAMPLE DATE	STATION B	STATION C	STATION D	STATION F	STATION DMC
Oct-1999	11-Oct	30	0.8	8.1	0.9	0.7
	13-Oct	29	0.5	6.4	0.8	0
	15-Oct	24	0.5	3	1	0
Nov-1999	8-Nov	55	0.4	8.1	1	0.5
	10-Nov	58	0.5	7.5	1.1	0
	12-Nov	36	0.6	5.4	1	0
Dec-1999	13-Dec	54	0.8	9	1	0.5
	15-Dec	40	0.7	9.7	0.9	0.6
	17-Dec	72	0	10	0.9	0.7
Jan-2000	3-Jan	77	0.8	7.8	0.6	0
	5-Jan	55	0.4	6.7	0.9	0
	7-Jan	76	0.5	8.4	0.8	0
Feb-2000	7-Feb	66	0.8	16	0.7	0.6
	9-Feb	72	0	22	0.9	0.6
	11-Feb	63	0	17	0.9	0.5
Mar-2000	6-Mar	81	1.2	24	1.1	0.6
	8-Mar	90	0.6	27	1.1	0.6
	10-Mar	79	0.8	23	1.2	0.8
Apr-2000	3-Apr	87	1.8	36	2.2	0
	5-Apr	74	1.7	39	1.1	0.8
	7-Apr	80	1.3	31	1.7	0.9
May-2000	1-May	85	1.6	55	1.6	0.6
	3-May	74	1.6	55	1.3	0
	5-May	78	1	60	1.2	0.6
Jun-2000	12-Jun	54	1.3	40	1.2	1.1
	14-Jun	43	2.1	28	1.2	0.8
	16-Jun	37	2.2	34	1.1	0.8
Jul-2000	10-Jul	42	1.7	31	1	0.4
	12-Jul	35	1.3	33	1	0.4
	14-Jul	32	0.9	30	0.9	0
Aug-2000	14-Aug	24	1.2	26	0.6	0
	16-Aug	23	1	20	0.6	0
	18-Aug	28	0.8	24	1.6	0
Sep-2000	11-Sep	52	0.6	32	0.7	0
	13-Sep	45	0.5	21	0.6	0
	15-Sep	40	0.8	17	0.7	0

TABLE A2: Sulfate (mg/L) as Measured by the Bureau of Reclamation

MONTH	SAMPLE DATE	STATION				
		B	C	D	F	DMC
Oct-1999	11-Oct	1460	69	382	176	58
	13-Oct	1560	69	342	172	20
	15-Oct	1400	70	285	147	19
Nov-1999	8-Nov	1370	107	345	172	61
	10-Nov	1130	111	324	164	23
	12-Nov	1230	108	272	170	22
Dec-1999	13-Dec	1380	203	395	278	64
	15-Dec	1350	222	461	274	30
	17-Dec	1490	216	436	287	80
Jan-2000	3-Jan	1520	182	326	324	51
	5-Jan	1400	206	336	312	25
	7-Jan	1430	205	381	322	25
Feb-2000	7-Feb	1600	233	572	343	107
	9-Feb	1540	222	637	337	99
	11-Feb	1390	260	573	272	64
Mar-2000	6-Mar	1600	296	711	277	47
	8-Mar	1710	311	771	262	37
	10-Mar	1600	312	702	266	51
Apr-2000	3-Apr	1740	358	979	198	32
	5-Apr	1630	384	1010	189	31
	7-Apr	NA	NA	NA	NA	NA
May-2000	1-May	1990	480	1560	239	39
	3-May	1730	502	1560	197	38
	5-May	1850	373	1530	203	40
Jun-2000	12-Jun	1290	283	1040	149	31
	14-Jun	1230	310	946	148	50
	16-Jun	1220	397	1020	167	49
Jul-2000	10-Jul	1350	250	1100	133	18
	12-Jul	1200	271	1130	137	34
	14-Jul	1200	325	1090	142	18
Aug-2000	14-Aug	1130	289	1110	110	23
	16-Aug	1050	208	923	118	17
	18-Aug	1210	175	1120	115	15
Sep-2000	11-Sep	1110	58	675	101	23
	13-Sep	1090	55	505	135	22
	15-Sep	1050	71	508	136	36

TABLE A3: Conductivity (μS) of Water Received at the BES Laboratory

MONTH	SAMPLE DATE	STATION B	STATION C	STATION D	STATION F	STATION DMC
Oct-1999	11-Oct	4200	756	1539	1121	511
	13-Oct	3720	750	1332	1056	364
	15-Oct	3780	740	1208	948	349
Nov-1999	8-Nov	4140	1053	1642	1242	598
	10-Nov	4120	1002	1569	1113	440
	12-Nov	3820	1060	1386	1179	463
Dec-1999	13-Dec	4090	1512	1980	1747	622
	15-Dec	4020	1585	2120	1725	625
	17-Dec	4470	1573	2120	1775	713
Jan-2000	3-Jan	4190	1261	1590	1878	503
	5-Jan	3830	1438	1620	1843	404
	7-Jan	4090	1436	1772	1895	367
Feb-2000	7-Feb	3970	1408	2130	1696	622
	9-Feb	4510	1667	2630	1834	696
	11-Feb	4320	1745	2440	1635	523
Mar-2000	6-Mar	4840	1919	2920	1621	377
	8-Mar	4980	1980	3060	1571	295
	10-Mar	4720	2020	2880	1583	383
Apr-2000	3-Apr	4850	2010	3490	1266	265
	5-Apr	3720	1670	2870	1070	242
	7-Apr	3950	1987	2780	1165	460
May-2000	1-May	NA	2405	2088	808	371
	3-May	NA	2194	2103	1211	394
	5-May	NA	1448	2075	1074	520
Jun-2000	12-Jun	2480	530	750	NA	238
	14-Jun	NA	NA	NA	NA	NA
	16-Jun	6380	3040	5520	1900	707
Jul-2000	10-Jul	1410	1355	1400	986	266
	12-Jul	300	1000	2020	600	400
	14-Jul	3600	1100	2800	1100	300
Aug-2000	14-Aug	1300	1200	2400	900	250
	16-Aug	3400	1200	2900	1000	220
	18-Aug	3200	1420	1100	1100	280
Sep-2000	11-Sep	1950	420	1450	620	250
	13-Sep	360	555	1700	1050	295
	15-Sep	2000	650	1700	1100	350

TABLE A4: Total Suspended Solids (mg/L) of Water Received at the BES Laboratory

MONTH	SAMPLE	STATION				
		B	C	D	F	DMC
Oct-1999	11-Oct	21	31	46	106	22
	13-Oct	41	37	39	0.8	12
	15-Oct	61	30	45	1	30
Nov-1999	8-Nov	56	27	26	1	15
	10-Nov	35	14	21	1.1	11
	12-Nov	42	35	29	1	6
Dec-1999	13-Dec	43	35	19	1	19
	15-Dec	21	11	15	0.9	0
	17-Dec	40	14	18	0.9	0
Jan-2000	3-Jan	36	19	41	0.6	12
	5-Jan	25	13	17	0.9	4
	7-Jan	34	17	21	0.8	7
Feb-2000	7-Feb	23	42	45	0.7	4
	9-Feb	48	40	52	0.9	21
	11-Feb	48	78	53	0.9	15
Mar-2000	6-Mar	NA	NA	27	1.1	NA
	8-Mar	NA	NA	41	1.1	5
	10-Mar	NA	47	43	1.2	16
Apr-2000	3-Apr	4.8	9	4.7	2.2	2.3
	5-Apr	14.1	13.1	10	1.1	4.1
	7-Apr	5.1	14.1	8.9	1.7	5.4
May-2000	1-May	104	88	162	1.6	NA
	3-May	100	45	193	1.3	NA
	5-May	76	174	133	1.2	NA
Jun-2000	12-Jun	18	4	21	1.2	22
	14-Jun	15	23	16	1.2	NA
	16-Jun	10	33	22	1.1	40
Jul-2000	10-Jul	17	27	23	1	3
	12-Jul	9	43	29	1	5
	14-Jul	38	26	41	0.9	3
Aug-2000	14-Aug	17	39	19	0.6	5
	16-Aug	17	22	24	0.6	5
	18-Aug	44	16	61	1.6	18
Sep-2000	11-Sep	59	80	85	0.7	12
	13-Sep	39	35	58	0.6	16
	15-Sep	49	10	67	0.7	19

TABLE A5: Dissolved Oxygen (mg/L) of Water Received at the BES Laboratory

MONTH	SAMPLE DATE	STATION B	C	D	F	DMC
Oct-1999	11-Oct	10.2	9.2	8.0	7.9	8.5
	13-Oct	9.9	6.4	8.2	9.3	10.6
	15-Oct	9.5	6.6	8.0	8.9	9.3
Nov-1999	8-Nov	12.4	9.2	8.5	11.3	10.4
	10-Nov	13.2	9.1	10.0	10.1	10.4
	12-Nov	12.9	13.1	12.6	12.6	11.6
Dec-1999	13-Dec	10.7	10.6	9.9	9.7	9.8
	15-Dec	12.2	11.2	10.9	10.9	10.8
	17-Dec	14.0	12.0	11.2	12.0	12.0
Jan-2000	3-Jan	14.8	15.3	15.1	15.0	14.7
	5-Jan	14.7	12.1	13.0	12.2	12.2
	7-Jan	12.4	13.0	12.3	11.1	11.9
Feb-2000	7-Feb	12.9	10.3	11.0	10.2	10.2
	9-Feb	13.0	9.8	10.9	10.5	10.5
	11-Feb	13.3	13.1	12.5	12.1	12.1
Mar-2000	6-Mar	11.9	10.3	11.0	10.8	10.8
	8-Mar	12.2	11.2	11.6	11.5	12.3
	10-Mar	11.2	10.4	12.4	11.5	12.5
Apr-2000	3-Apr	10.1	10.3	10.7	10.0	11.0
	5-Apr	14.3	15.1	14.0	13.0	12.4
	7-Apr	10.4	9.7	9.5	8.5	8.7
May-2000	1-May	11.3	8.5	10.9	10.5	10.5
	3-May	13.9	12.1	12.7	10.1	12.5
	5-May	12.8	12.9	12.0	12.6	13.8
Jun-2000	12-Jun	14.3	15.1	15.9	14.5	14.8
	14-Jun	11.6	10.0	11.4	9.8	11.0
	16-Jun	12.3	11.1	12.3	12.4	12.5
Jul-2000	10-Jul	13.3	12.1	12.7	12.7	11.3
	12-Jul	13.7	13.5	15.0	13.5	13.4
	14-Jul	12.7	12.0	13.5	12.8	12.2
Aug-2000	14-Aug	8.3	8.0	8.2	8.0	11.4
	16-Aug	8.1	8.1	8.0	8.3	8.7
	18-Aug	8.2	8.0	8.5	8.4	8.9
Sep-2000	11-Sep	8.7	7.6	8.0	7.5	8.3
	13-Sep	7.0	7.2	7.1	6.8	7.1
	15-Sep	6.5	6.7	6.7	6.6	6.5

TABLE A6: pH of Site Water as Received at the BES Laboratory

MONTH	SAMPLE DATE	STATION				
		B	C	D	F	DMC
Oct-1999	11-Oct	7.7	7.6	7.2	7.3	7.4
	13-Oct	7.8	7.4	7.8	8.0	8.1
	15-Oct	7.7	7.4	7.4	7.4	7.8
Nov-1999	8-Nov	8.2	8.0	7.9	7.9	8.5
	10-Nov	8.0	8.1	7.9	7.8	8.0
	12-Nov	8.1	8.2	8.0	7.9	8.1
Dec-1999	13-Dec	8.2	8.2	8.1	8.0	8.1
	15-Dec	8.2	8.2	8.1	7.9	8.1
	17-Dec	8.1	8.1	7.9	7.8	7.9
Jan-2000	3-Jan	8.0	8.2	8.0	7.9	8.0
	5-Jan	7.9	8.0	7.9	7.8	7.9
	7-Jan	8.1	8.1	8.0	7.7	7.9
Feb-2000	7-Feb	7.9	7.8	7.8	7.6	7.6
	9-Feb	7.9	7.8	7.8	7.5	7.6
	11-Feb	8.0	8.0	7.9	7.9	7.9
Mar-2000	6-Mar	8.2	8.1	8.1	7.9	7.9
	8-Mar	8.1	8.1	8.1	7.7	7.6
	10-Mar	8.2	7.9	8.1	7.8	7.5
Apr-2000	3-Apr	8.4	8.2	8.2	8.1	8.1
	5-Apr	8.0	8.2	8.1	8.1	8.3
	7-Apr	8.6	8.6	8.5	8.4	8.4
May-2000	1-May	8.3	8.1	8.0	8.0	8.2
	3-May	8.5	8.2	8.2	7.7	8.5
	5-May	8.3	8.2	8.1	7.9	8.2
Jun-2000	12-Jun	8.4	8.4	8.4	7.8	7.7
	14-Jun	8.4	8.4	8.3	8.2	8.3
	16-Jun	8.3	8.5	8.3	7.8	7.8
Jul-2000	10-Jul	8.4	8.8	8.5	7.7	7.8
	12-Jul	8.0	8.1	8.0	7.7	7.9
	14-Jul	8.5	8.5	8.5	7.7	7.8
Aug-2000	14-Aug	8.2	7.6	8.1	7.7	8.0
	16-Aug	8.0	7.8	8.0	7.8	7.6
	18-Aug	8.0	7.5	8.2	7.8	7.8
Sep-2000	11-Sep	8.3	8.2	8.3	7.9	8.2
	13-Sep	7.0	7.0	7.0	7.0	7.0
	15-Sep	7.0	7.0	7.0	7.0	7.0

TABLE A7: Salinity (ppt) of Water Received at the BES Laboratory

MONTH	SAMPLE	STATION				
		B	C	D	F	DMC
Oct-1999	11-Oct	2.5	0.3	0.8	0.6	0.2
	13-Oct	2.2	0.3	0.7	0.5	0.1
	15-Oct	2.2	0.3	0.6	0.5	0.1
Nov-1999	8-Nov	2.4	0.5	0.9	0.6	0.2
	10-Nov	2.4	0.5	0.8	0.6	0.2
	12-Nov	2.2	0.5	0.7	0.6	0.2
Dec-1999	13-Dec	2.4	0.8	1.1	0.9	0.3
	15-Dec	2.3	0.8	1.2	0.9	0.3
	17-Dec	2.6	0.8	1.1	0.9	0.3
Jan-2000	3-Jan	2.4	0.6	0.8	1.0	0.2
	5-Jan	2.2	0.7	0.9	0.9	0.1
	7-Jan	2.4	0.7	0.9	1.0	0.1
Feb-2000	7-Feb	2.1	0.8	1.3	0.9	0.3
	9-Feb	2.6	0.9	1.4	1.0	0.3
	11-Feb	2.5	0.9	1.3	0.9	0.2
Mar-2000	6-Mar	2.9	2.0	1.7	0.9	0.1
	8-Mar	2.9	1.1	1.8	1.8	0.1
	10-Mar	2.8	1.1	1.6	0.8	0.1
Apr-2000	3-Apr	2.8	1.1	2.0	0.7	0.0
	5-Apr	2.1	0.9	1.6	0.5	0.0
	7-Apr	2.3	1.1	1.6	0.6	0.2
May-2000	1-May	NA	1.1	1.1	0.8	0.2
	3-May	NA	1.1	1.1	0.8	0.1
	5-May	NA	1.0	1.1	0.8	0.3
Jun-2000	12-Jun	4.0	0.2	0.2	2.1	0.0
	14-Jun	4.0	3.0	4.0	4.0	NA
	16-Jun	3.6	1.6	3.1	1.0	0.3
Jul-2000	10-Jul	2.0	2.0	2.0	0.3	0.1
	12-Jul	2.0	0.8	1.0	0.5	0.2
	14-Jul	2.0	0.5	1.5	0.5	0.1
Aug-2000	14-Aug	1.0	0.5	1.5	0.5	0.1
	16-Aug	2.0	0.4	2.0	1.0	0.0
	18-Aug	2.0	0.4	0.5	0.5	0.1
Sep-2000	11-Sep	1.0	0.1	1.0	0.2	0.1
	13-Sep	2.3	0.5	1.2	0.8	0.1
	15-Sep	2.0	0.1	1.2	0.7	0.1

TABLE A8: Alkalinity (as $CaCO_3$) of Water Received at the BES Laboratory

MONTH	SAMPLE	STATION				
		B	C	D	F	DMC
Oct-1999	11-Oct-99	206	188	202	178	112
	13-Oct-99	206	230	190	170	74
	15-Oct-99	200	204	198	166	74
Nov-1999	8-Nov-99	240	178	196	354	68
	10-Nov-99	190	194	210	156	86
	12-Nov-99	200	220	188	280	72
Dec-1999	13-Dec-99	198	240	242	210	96
	15-Dec-99	198	238	230	174	74
	17-Dec-99	194	242	232	200	100
Jan-2000	3-Jan-00	194	252	198	248	86
	5-Jan-00	236	254	228	230	90
	7-Jan-00	244	250	240	246	86
Feb-2000	7-Feb-00	252	324	292	278	186
	9-Feb-00	214	278	250	210	120
	11-Feb-00	176	258	250	188	92
Mar-2000	6-Mar-00	258	274	258	190	84
	8-Mar-00	NA	278	240	196	66
	10-Mar-00	216	296	302	194	78
Apr-2000	3-Apr-00	296	322	224	NA	76
	5-Apr-00	136	272	218	186	104
	7-Apr-00	76	254	284	176	136
May-2000	1-May-00	120	114	NA	NA	NA
	3-May-00	114	120	180	180	112
	5-May-00	120	132	186	186	94
Jun-2000	12-Jun-00	160	186	574	82	164
	14-Jun-00	154	182	812	NA	82
	16-Jun-00	150	214	470	134	NA
Jul-2000	10-Jul-00	160	198	174	130	66
	12-Jul-00	154	184	174	130	110
	14-Jul-00	162	272	164	156	96
Aug-2000	14-Aug-00	204	156	162	150	64
	16-Aug-00	184	160	44	146	28
	18-Aug-00	92	178	166	NA	NA
Sep-2000	11-Sep-00	136	162	198	120	84
	13-Sep-00	194	136	148	158	84
	15-Sep-00	158	152	160	316	134

NA=Not Available

TABLE A9: Hardness (as $CaCO_3$) of Water Received at the BES Laboratory

MONTH	SAMPLE	STATION				
		B	C	D	F	DMC
Oct-1999	**11-Oct**	1150	120	360	270	126
	13-Oct	1112	190	358	240	96
	15-Oct	1100	188	330	260	78
Nov-1999	**8-Nov**	1122	240	362	354	140
	10-Nov	1104	256	360	156	133
	12-Nov	1018	238	316	280	86
Dec-1999	**13-Dec**	1126	240	464	366	194
	15-Dec	1082	238	510	352	164
	17-Dec	1176	242	470	352	154
Jan-2000	**3-Jan**	1162	306	364	430	86
	5-Jan	1124	316	390	410	90
	7-Jan	1186	320	396	406	86
Feb-2000	**7-Feb**	970	352	600	446	208
	9-Feb	662	326	592	398	168
	11-Feb	998	332	540	348	134
Mar-2000	**6-Mar**	NA	518	604	360	108
	8-Mar	NA	362	616	332	92
	10-Mar	126	366	604	359	96
Apr-2000	**3-Apr**	1218	460	778	NA	98
	5-Apr	96	412	882	370	138
	7-Apr	144	370	710	276	196
May-2000	**1-May**	196	202	NA	NA	NA
	3-May	202	196	NA	318	92
	5-May	196	218	184	288	198
Jun-2000	**12-Jun**	978	308	638	90	228
	14-Jun	966	338	844	NA	100
	16-Jun	922	438	442	272	104
Jul-2000	**10-Jul**	928	306	814	228	88
	12-Jul	916	212	864	228	114
	14-Jul	960	378	840	234	72
Aug-2000	**14-Aug**	134	344	894	182	136
	16-Aug	782	284	732	268	92
	18-Aug	872	402	866	NA	NA
Sep-2000	**11-Sep**	862	160	534	290	358
	13-Sep	898	321	512	400	180
	15-Sep	816	194	454	346	206

NA=Not Available

TABLE A10: Temperature (C) of Water Received at the BES Laboratory

MONTH	SAMPLE DATE	STATION B	C	D	F	DMC
Oct-1999	11-Oct	5.4	6.3	6.3	5.5	10.2
	13-Oct	2.0	6.1	2.3	2.3	2.0
	15-Oct	10.3	8.0	7.8	7.2	7.4
Nov-1999	8-Nov	15.3	13.9	12.8	13.7	13.3
	10-Nov	2.8	6.8	10.8	6.8	8.2
	12-Nov	12.0	10.6	4.8	9.9	10.5
Dec-1999	13-Dec	6.0	4.8	4.5	3.0	3.7
	15-Dec	8.1	8.3	7.0	9.2	7.2
	17-Dec	1.3	1.9	1.4	4.8	1.2
Jan-2000	3-Jan	7.5	6.9	6.4	6.2	5.7
	5-Jan	1.0	0.1	1.2	2.0	0.1
	7-Jan	1.7	1.6	1.5	1.8	4.0
Feb-2000	7-Feb	12.3	13.5	12.7	12.9	12.7
	9-Feb	3.8	5.0	3.0	5.0	3.5
	11-Feb	3.1	3.0	2.4	3.0	4.2
Mar-2000	6-Mar	5.4	8.8	8.9	6.4	12.7
	8-Mar	14.7	14.7	14.7	14.3	13.9
	10-Mar	3.8	3.8	3.8	3.8	3.8
Apr-2000	3-Apr	19.3	20.9	21.0	18.4	17.7
	5-Apr	3.0	3.0	3.0	3.0	3.0
	7-Apr	3.2	2.2	2.3	4.1	3.0
May-2000	1-May	11.0	11.0	12.1	12.1	15.0
	3-May	11.3	14.2	11.7	17.5	15.4
	5-May	4.0	5.1	6.3	7.0	4.0
Jun-2000	12-Jun	24.0	24.0	24.0	24.0	24.0
	14-Jun	7.2	11.5	11.4	12.6	11.0
	16-Jun	6.9	6.9	6.9	6.9	6.7
Jul-2000	10-Jul	23.8	23.3	22.2	21.9	24.5
	12-Jul	20.9	16.4	16.3	14.9	17.3
	14-Jul	22.1	21.0	18.4	18.6	18.9
Aug-2000	14-Aug	5.9	5.9	5.9	5.9	5.9
	16-Aug	6.0	6.0	6.0	6.0	6.0
	18-Aug	4.8	4.8	4.8	4.8	4.8
Sep-2000	11-Sep	6.2	6.2	6.2	6.2	6.2
	13-Sep	5.3	5.3	5.3	5.3	5.3
	15-Sep	5.7	5.7	5.7	5.7	5.7

TABLE A11: Ammonia (ppm as Nitrogen) of Water Received at the BES Laboratory

MONTH	SAMPLE	STATION				
		B	C	D	F	DMC
Oct-1999	11-Oct	3.70	0.98	0.61	0.73	0.37
	13-Oct	3.70	0.61	0.73	0.61	0.12
	15-Oct	1.80	0.61	0.37	0.61	0.12
Nov-1999	8-Nov	3.10	0.49	0.24	0.61	0.12
	10-Nov	3.70	0.00	0.00	0.73	0.00
	12-Nov	3.70	0.37	0.24	0.73	0.00
Dec-1999	13-Dec	3.70	0.36	0.49	0.37	0.12
	15-Dec	3.10	0.37	0.37	0.24	0.12
	17-Dec	3.70	0.37	0.61	0.37	0.00
Jan-2000	3-Jan	3.10	0.24	0.37	0.37	0.00
	5-Jan	4.27	0.37	0.37	0.61	0.13
	7-Jan	4.80	0.43	0.61	0.61	0.06
Feb-2000	7-Feb	2.90	0.70	0.92	0.40	0.09
	9-Feb	0.31	0.98	0.98	0.81	0.43
	11-Feb	2.20	1.50	0.98	0.98	0.24
Mar-2000	6-Mar	4.27	0.61	0.87	0.73	0.37
	8-Mar	3.66	0.00	1.22	0.74	0.12
	10-Mar	4.30	0.63	0.00	0.00	0.35
Apr-2000	3-Apr	4.15	1.59	2.20	0.62	0.37
	5-Apr	0.37	1.46	2.32	0.65	0.59
	7-Apr	4.30	1.10	1.71	0.73	0.37
May-2000	1-May	NA	0.61	0.92	NA	0.34
	3-May	0.23	0.39	0.49	NA	0.12
	5-May	NA	NA	0.48	0.00	0.12
Jun-2000	12-Jun	0.52	1.09	0.39	0.37	0.39
	14-Jun	1.51	1.32	0.16	0.26	NA
	16-Jun	1.46	1.95	1.10	1.22	0.18
Jul-2000	10-Jul	0.37	0.85	0.62	1.10	0.55
	12-Jul	0.79	0.76	0.77	0.95	0.26
	14-Jul	0.55	0.92	0.62	2.44	0.24
Aug-2000	14-Aug	0.12	0.61	0.37	0.61	0.06
	16-Aug	0.12	0.27	0.24	0.61	0.12
	18-Aug	0.00	0.00	0.06	0.06	0.00
Sep-2000	11-Sep	0.00	0.20	0.00	0.61	0.00
	13-Sep	0.01	1.22	0.25	1.22	0.00
	15-Sep	0.49	0.67	0.43	0.01	0.00

NA=Not Available

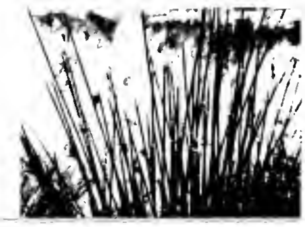
TABLE A12: Total Chlorine (mg/L) of Water Received at the BES Laboratory

MONTH	SAMPLE	STATION				
		B	C	D	F	DMC
Oct-1999	11-Oct	0.20	0.20	0.10	0.10	0.00
	13-Oct	0.20	0.20	0.10	0.10	0.00
	15-Oct	0.20	0.10	0.10	0.10	0.00
Nov-1999	8-Nov	0.10	0.00	0.00	0.00	0.00
	10-Nov	0.15	0.00	0.00	0.00	0.00
	12-Nov	0.20	0.00	0.00	0.00	0.00
Dec-1999	13-Dec	0.10	0.00	0.00	0.00	0.00
	15-Dec	0.10	0.00	0.00	0.00	0.00
	17-Dec	0.10	0.00	0.00	0.00	0.00
Jan-2000	3-Jan	0.10	0.00	0.00	0.00	0.00
	5-Jan	0.10	0.10	0.10	0.10	0.10
	7-Jan	0.30	0.10	0.10	0.10	0.00
Feb-2000	7-Feb	0.05	0.03	0.05	0.00	0.00
	9-Feb	0.10	0.10	0.10	0.00	0.00
	11-Feb	*	0.10	0.10	0.10	0.00
Mar-2000	6-Mar	0.02	0.00	0.00	0.00	0.10
	8-Mar	0.00	0.00	0.00	0.00	0.10
	10-Mar	0.00	0.00	0.00	0.00	0.10
Apr-2000	3-Apr	0.00	0.00	0.00	0.00	0.00
	5-Apr	0.00	0.00	0.00	0.00	0.00
	7-Apr	0.20	0.20	0.20	0.20	0.10
May-2000	1-May	0.20	0.20	0.00	NA	0.10
	3-May	0.20	0.20	0.30	NA	0.00
	5-May	0.10	0.00	0.10	0.00	0.10
Jun-2000	12-Jun	0.00	0.50	0.20	0.00	0.00
	14-Jun	0.00	0.00	0.00	0.00	0.00
	16-Jun	0.20	0.80	0.30	0.40	0.12
Jul-2000	10-Jul	0.10	0.30	0.20	0.10	0.10
	12-Jul	0.10	0.20	0.10	0.10	0.10
	14-Jul	0.20	0.90	0.30	0.30	0.10
Aug-2000	14-Aug	0.16	0.25	0.15	0.20	0.10
	16-Aug	0.15	0.20	0.20	0.20	0.10
	18-Aug	0.10	0.20	0.20	0.15	0.10
Sep-2000	11-Sep	0.30	0.25	0.25	0.30	0.30
	13-Sep	0.20	0.30	0.25	0.40	0.30
	15-Sep	0.15	0.60	0.20	0.60	0.30

NA=Not Available
ND=Not Detected

* =Chlorine level measured at 2.5 mg/l, which is believed to be erroneous data

Tim McLaughlin,
U.S. Bureau of Reclamation



Purpose

Sediment monitoring for the Grassland Bypass Project (Project) focuses on measuring selenium and organic carbon parameters in the San Luis Drain (SLD), Mud Slough, and Salt Slough. The purpose of the monitoring is to assess the selenium concentrations in the sediment samples over the 5-year life of the Project and to provide characterization of selenium adsorption and desorption. The measurements within the SLD provide selenium concentration estimates for comparison with California Department of Health Services' hazardous waste criterion. The measurements in Mud and Salt Sloughs provide selenium concentrations for comparison with USFWS thresholds for ecological risk.

Sampling Locations

Sampling locations for sediment monitoring (Stations A, B, C, D, E, F, and I) are defined in the Project's Compliance Monitoring Plan and depicted in Figure 2, Chapter 1. At the request of USFWS, sediment monitoring within Salt Slough (Station F) was changed from Lander Avenue to a location upstream of the San Luis National Wildlife Refuge used by USFWS for biota monitoring. This change was made for the September 1997 sampling event.

Sampling Frequency

Quarterly sampling periods are November, March, June, and September for each of the water years. The sampling periods correspond with the biota sampling events of the USFWS.

Sampling frequency includes quarterly measurements for Stations A and B (within the San Luis Drain), Station F (within Salt Slough), Stations C, D, and E (within Mud Slough). Annual measurements are included for Station I (backwaters of Mud Slough). Additional annual measurements are made for 10 locations in the SLD.

Sampling Methods

Sediment samples are collected using an acrylic coring device (4.5 cm diameter, 38 cm internal length). After collecting the sediment, sections of the core, 0-3 cm and 3-8 cm, are slowly extruded using a non-metallic internal pushing device and placed in distinct quart size mixing bowls. An additional sample is collected near the same spot for the whole-core sample and placed into a third mixing bowl. The process is continued until three samples along a transect are completed. Material from the 2nd and 3rd samples are placed in the corresponding

Figure 1. Station A: Selenium in Sediment

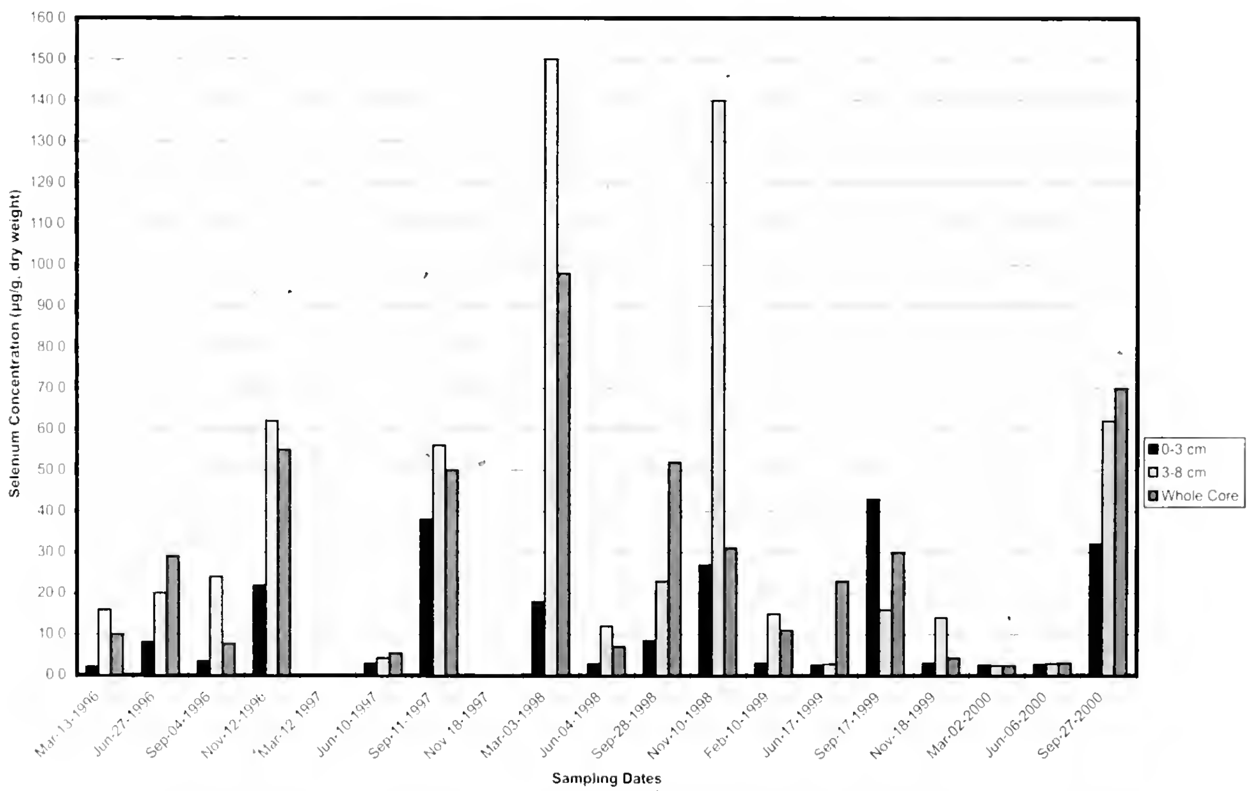


Figure 2. Station B: Selenium in Sediment

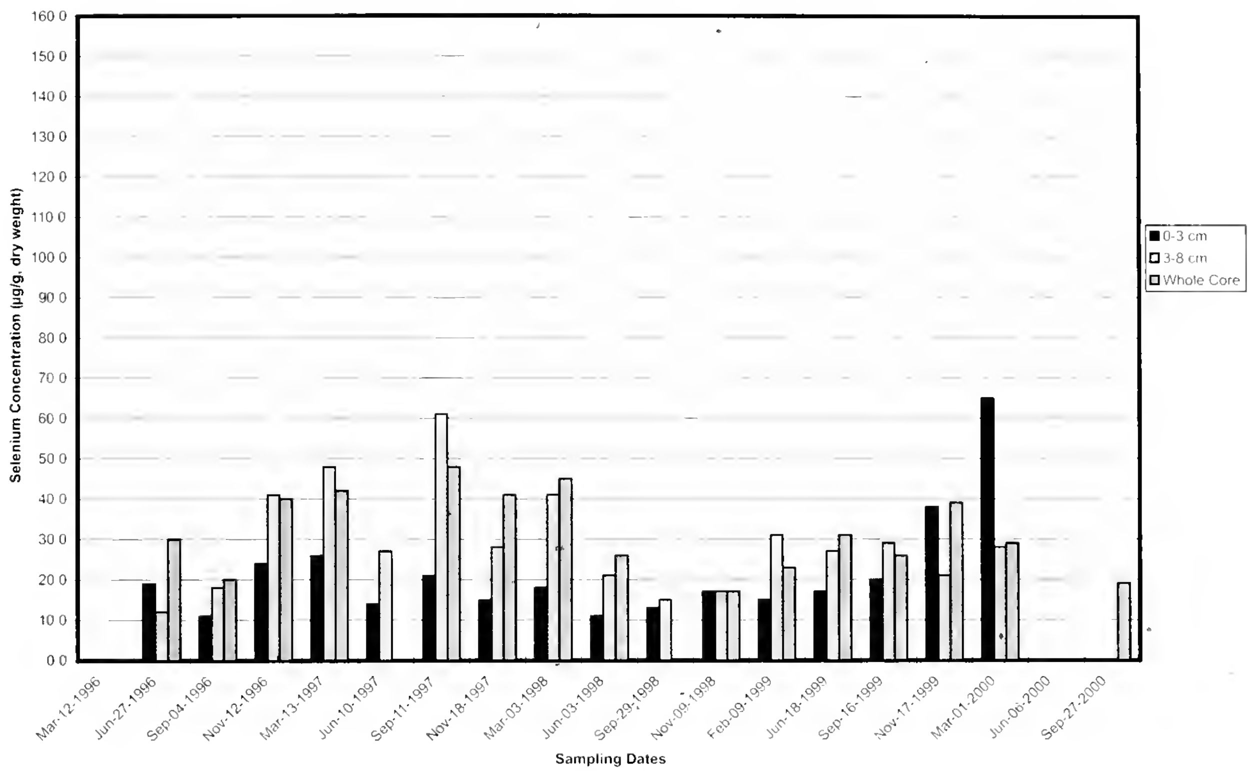


Figure 3. Station C: Selenium in Sediment

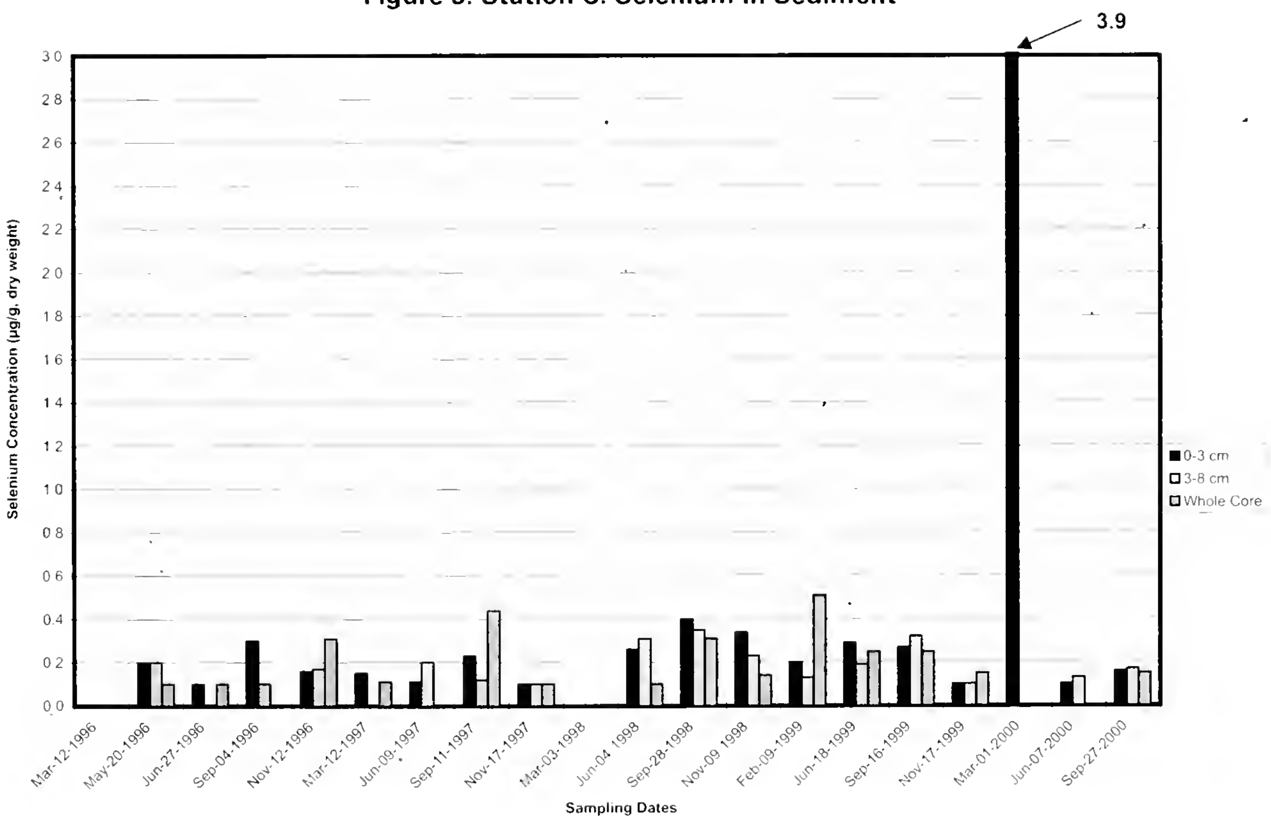
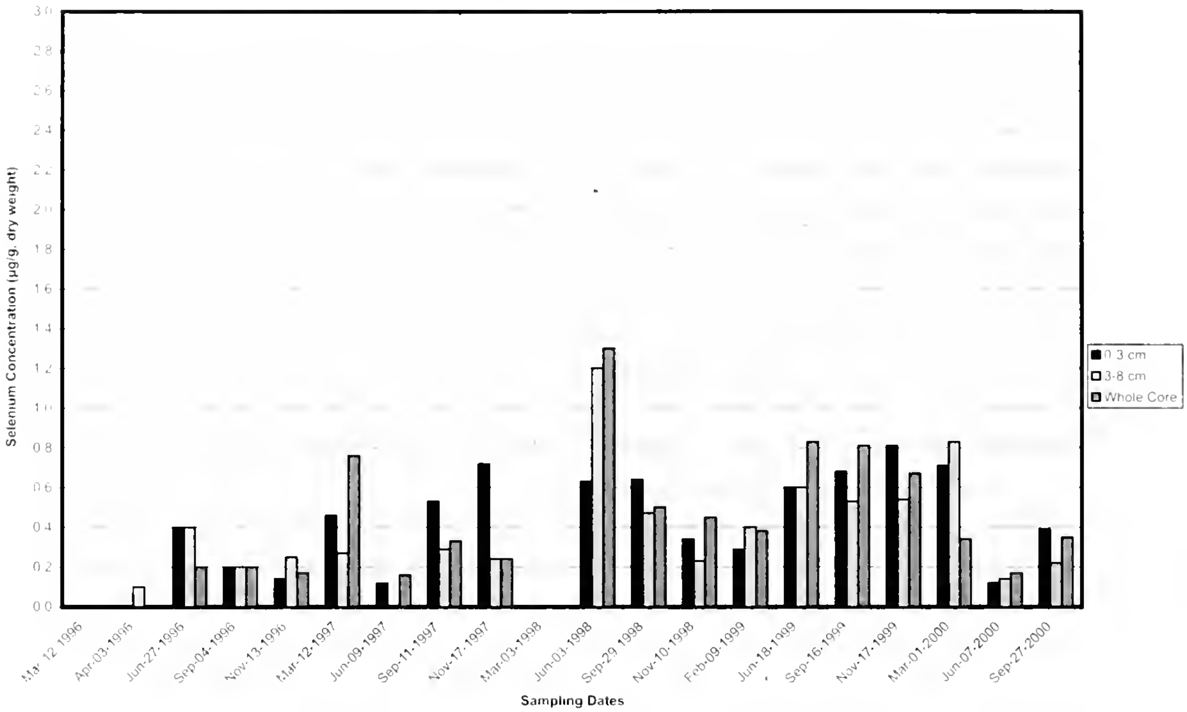


Figure 4. Station D: Selenium in Sediment



0-3 cm, 3-8 cm and whole-core mixing bowls containing the 1st samples. Each of the mixing bowls contain material from the transect. The 0-3 cm, 3-8 cm, and whole core samples are then mixed well in their mixing bowls in a manner similar to kneading bread. The mixing objective is to get one homogeneous sample in each of the bowls. Composited samples are then placed in a wide-mouth polyethylene container and stored in an ice chest at 4°C.

Results

Table 1 shows information from all of the stations describing each sampling period, each core partition, and each parameter. All values are based on dry weight. Figures 1 through 7 depict the same selenium information with the help of bar charts. Further discussion is limited to selenium concentrations only. Data are compared to the following:

Guidelines:

- the recommended ecological risk guidelines for selenium concentrations in sediment (Table 1, Chapter 7) are as follows: no effect - less than 2 µg/g, dry weight, level of concern - 2 to 4 µg/g, dry weight, and toxicity — greater than 4 µg/g, dry weight.

Criteria:

- the California Department of Health Services established a criterion for selenium concentration in sediment of 100 µg/g wet weight. Should the selenium concentrations in the SLD sediments exceeds this value, material dredged from the bottom of the drain would have to be disposed of at a hazardous waste site.

With one exception, selenium concentrations in the sediment from within-slough sampling stations (Stations C, D, E, and F) were below the 2.0 µg/g no effect level for the last 8 quarterly sampling periods. In fact, all values except one were below 1.0 µg/g. The one exception occurred at Station C, upstream of the SLD outfall, during the March 1, 2000 sampling period, where the sample concentration value was 3.9 µg/g. The Quality Assurance Officer was concerned that data point and might represent an outlier. The sample was submitted for re-analysis. A second result was 4.3 µg/g. Therefore, the original sample value of 3.9 µg/g was accepted. The 3.9 µg/g is within the level of concern range for the recommended ecological risk guidelines. However, the 4.3 µg/g re-analyzed value exceeds the toxicity guideline.

The June 7, 2000 selenium concentration value from Station I (0-3 cm) of 4.4 µg/g exceeded the recommended ecological risk guideline toxicity level of greater than 4 µg/g. The June 7, 2000 results were 4.4

Figure 5. Station E: Selenium in Sediment

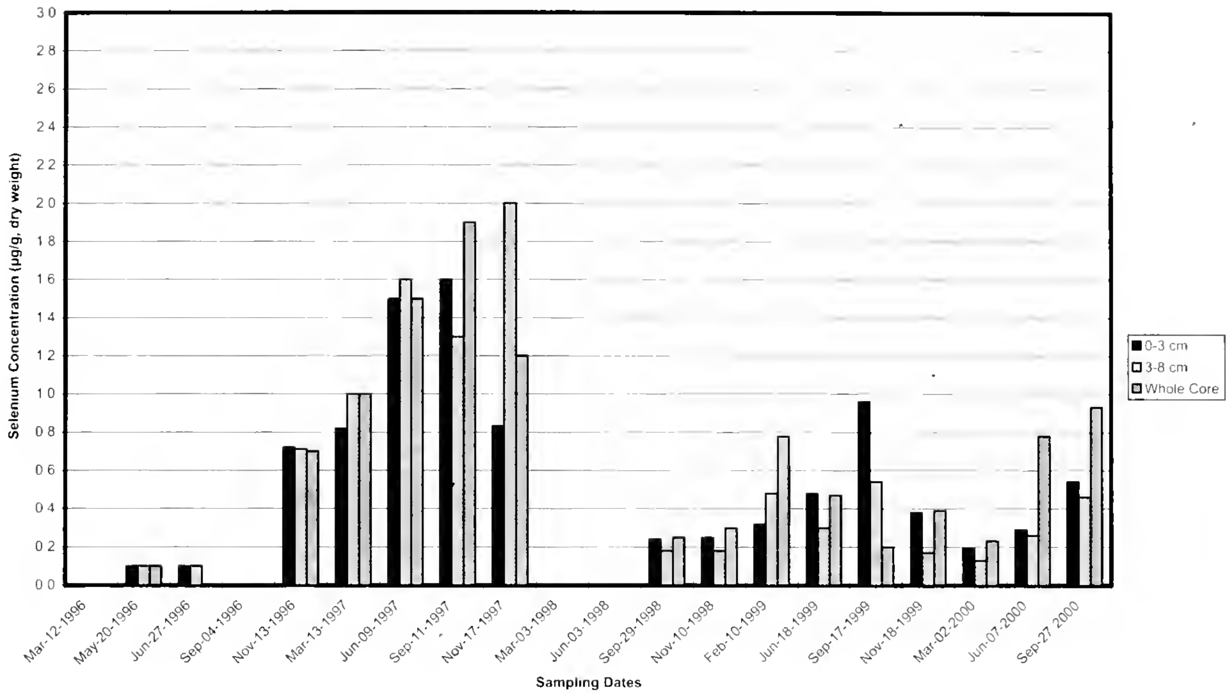


Figure 6. Station F: Selenium in Sediment

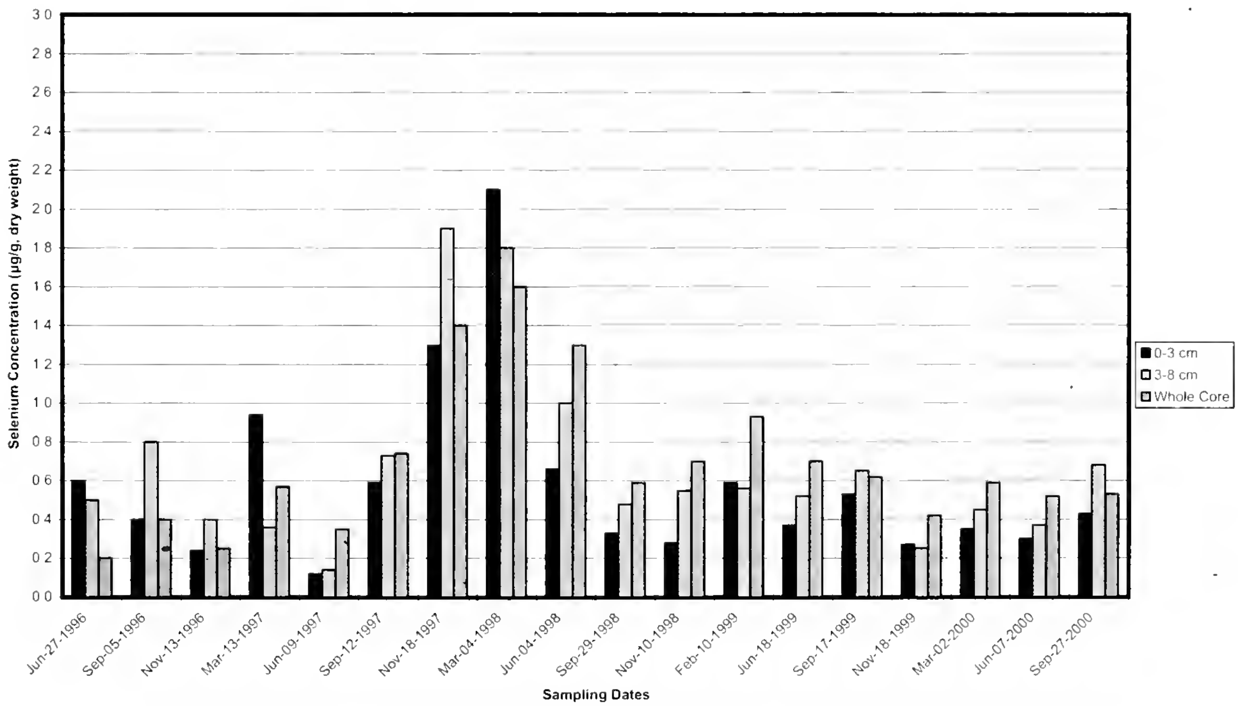
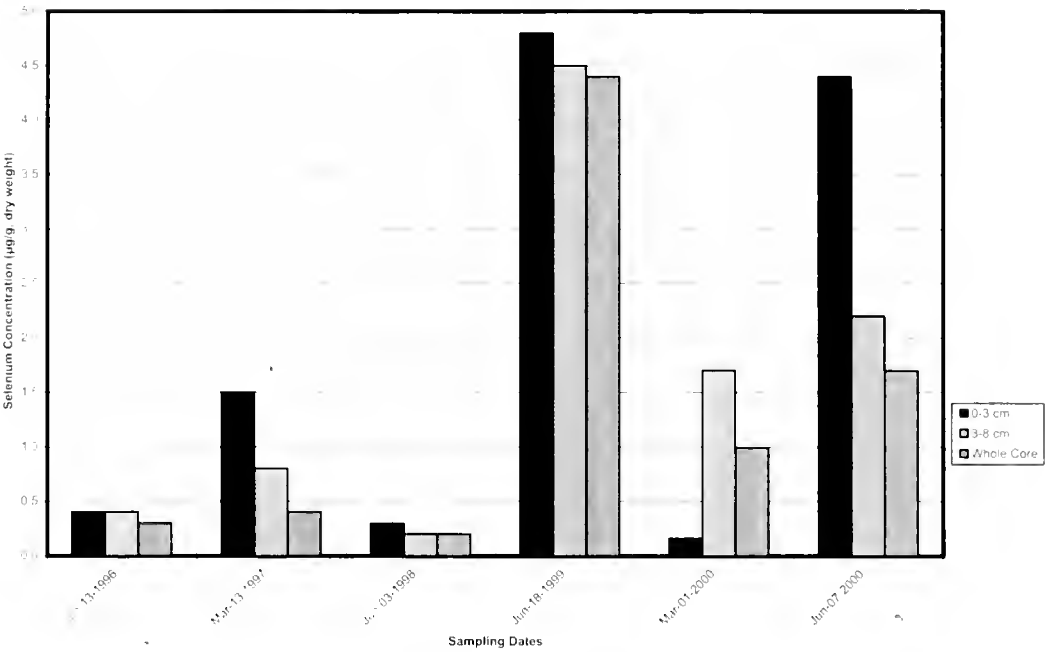


Figure 7. Station I: Selenium in Sediment



µg/g, 2.2 µg/g, and 1.7 µg/g, for 0-3 cm, 3-8 cm and whole core respectively, while the previous year's June measurements were 4.8, 4.5, and 4.4 respectively. Due to the higher levels reported from the June 18, 1999 survey, the station was sampled on March 1, 2000 during the regular spring quarterly sampling to determine if the higher levels were continuing. Those results were 0.16 µg/g, 1.7, µg/g, and 0.99 µg/g respectively. Station I is located along Mud Slough about 1.5 km downstream of the SLD outfall, where high winter and spring flows in Mud Slough can overtop the slough top channel to form a broad, shallow backwater on the east side of the slough.

Results from quarterly sampling within the SLD, Stations A and B, were consistent with the previous years values (Figures 1 and 2). For the entire period of record, the range of selenium concentration values from Station A were 2.0 - 43 µg/g (0-3 cm), 2.4 - 150 µg/g (3-8 cm), and 2.4 - 98 µg/g (whole core). For Station B, the ranges were 11 - 65 µg/g (0-3 cm), 12 - 61 µg/g (3-8 cm), and 0.11 - 48 µg/g (whole core). Similar variability was observed in the other 10 locations within the SLD. The highest selenium values from the SLD were 150 µg/g, 140 µg/g, 100 µg/g, and 100 µg/g. Converting the dry weight to wet weight [wet weight = (dry weight µg/g) * (1.0 - percent moisture/100.0)], provides wet weight values of: 55 µg/g, 56 µg/g, 40 µg/l, and 38 µg/g. These concentrations from the SLD are below the 100 µg/g wet weight hazardous material criterion established by the California Department of Health Services.

Quality Control

Laboratory Precision

Duplicate samples are two discrete samples (aliquots) taken from the same parent material and analyzed independently. The results, which should be similar, demonstrate the laboratory's ability to achieve consistent results. GBP Monitoring Program Quality Assurance protocol requires laboratory re-analysis if there is a relative percent difference (RPD) between duplicates greater than 35%. Table 2 shows results of the duplicate analyses. Over the last four years of sampling, 6 of the 49 duplicate samples differed by more than 35%. In each case, the re-analyzed results were similar to the original. For example, results of duplicate samples collected on November 12, 1996 at Station B were 41 µg/g and 26 µg/g, with an RPD of 44.8. Re-analysis yielded values of 42 µg/g and 28 µg/g, respectively, confirming the original results.

Sample Variability

To determine sample variability, two or more samples are collected from the same station during the same sampling event. Table 3 presents all replicate samples collected over the 4 years of the Project. Of the 18 replicate samples analyzed, 8 exceeded the QA objective of an RPD ≤ 35%.

Table 1. Summary of Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	µg/g, dry weight	µg/g, dry weight	µg/g, dry weight	%	%	%	%	%	%
Station A									
Mar-13-1996	2.0	16	10	3.9	3.6	3.4	83.3	79.1	80.5
Jun-27-1996	8.0	20	29	4.33	5.01	2.96	83.8	78.30	71.2
Sep-04-1996	3.4	24	7.7	4.35	2.72	4.10	81.2	73.3	76.0
Nov-12-1996	22	62	55	2.92	3.10	3.72	*	*	*
Mar-12-1997	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-10-1997	2.9	4.2	5.4	0.89	1.55	2.10	55.0	58.0	62.0
Sep-11-1997	38	56	50	1.52	2.18	1.95	70.6	75.7	70.2
Nov-18-1997	NT	NT	NT	NT	NT	NT	NT	NT	NT
Mar-03-1998	18	150	98	1.21	2.89	2.28	52.9	63.3	65.0
Jun-04-1998	2.8	12	7.0	0.58	1.58	1.03	35.2	54.9	50.0
Sep-28-1998	8.5	23	52	1.06	1.17	2.25	55.0	55.3	67.9
Nov-10-1998	27	140	31	1.55	2.61	1.43	71.0	60.1	59.6
Feb-10-1999	3.0	15	11	1.32	1.45	1.10	69.3	65.0	59.1
Jun-17-1999	2.5	2.7	23	1.03	1.01	1.34	49.6	52.9	56.3
Sep-17-1999	43	16	30	1.11	1.23	2.05	61.4	59.5	68.4
Nov-18-1999	2.9	14	4.3	0.80	1.36	0.93	55.6	59.1	53.3
Mar-02-2000	2.5	2.4	2.4	0.71	0.83	0.98	47.3	48.3	51.4
Jun-06-2000	2.6	2.8	3.0	0.92	0.86	0.87	43.3	44.4	44.1
Sep-27-2000	32	62	70	2.99	2.32	1.81	73.1	70.7	67.9
Station B									
Mar-12-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-27-1996	19	12	30	2.70	2.81	2.15	64.7	59.9	59.0
Sep-04-1996	11	18	20	3.85	3.75	2.08	66.5	61.7	51.2
Nov-12-1996	24	41	40	1.97	1.89	3.45	*	*	*
Mar-13-1997	26	48	42	2.49	2.36	2.66	*	*	*
Jun-10-1997	14	27	0.11	2.14	2.95	0.07	40.0	49.0	58.0
Sep-11-1997	21	61	48	2.39	2.82	1.84	65.9	61.4	53.8
Nov-18-1997	15	28	41	1.62	1.86	1.73	53.8	44.2	50.2
Mar-03-1998	18	41	45	1.46	1.70	1.73	50.8	51.4	54.3
Jun-03-1998	11	21	26	0.85	1.51	1.09	46.6	54.0	46.1
Sep-29-1998	13	15	NT	1.51	1.64	NT	85.9	79.5	NT
Nov-09-1998	17	17	17	1.68	1.74	1.76	73.2	80.8	56.7
Feb-09-1999	15	31	23	0.94	1.93	1.87	61.3	60.9	72.7
Jun-18-1999	17	27	31	1.45	1.84	1.28	56.1	61.4	47.1
Sep-16-1999	20	29	26	1.65	2.03	1.57	51.7	54.7	59.2
Nov-17-1999	38	21	39	2.23	1.96	1.92	58.8	55.6	55.9
Mar-01-2000	65	28	29	1.8	0.99	1.32	59.1	53.8	43.2
Jun-06-2000	NT	NT	NT	NT	NT	NT	NT	NT	NT
Sep-27-2000	NT	NT	19	NT	NT	0.62	NT	NT	40.9

Table 1 (continued). Summary of Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	µg/g, dry weight	µg/g, dry weight	µg/g, dry weight	%	%	%	%	%	%
Station C									
Mar-12-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
May-20-1996	0.2	0.2	0.1	0.8	0.6	0.6	38.5	39.4	36.6
Jun-27-1996	0.1	<0.10	0.1	0.49	0.40	0.14	34.0	30.0	25.2
Sep-04-1996	0.3	0.1	<0.10	0.38	0.53	0.53	33.1	36.5	40.6
Nov-12-1996	0.16	0.17	0.31	0.26	0.28	0.95	•	•	•
Mar-12-1997	0.15	<0.10	0.11	0.35	0.28	0.68	•	•	•
Jun-09-1997	0.11	0.20	<0.10	0.31	0.27	0.16	30.0	53.0	28.0
Sep-11-1997	0.23	0.12	0.44	0.41	0.19	0.92	32.7	24.3	38.6
Nov-17-1997	0.10	0.10	0.10	0.27	0.18	0.32	28.7	26.7	65.5
Mar-03-1998	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-04-1998	0.26	0.31	0.10	0.58	0.62	0.33	35.3	29.4	49.2
Sep-28-1998	0.40	0.35	0.31	0.77	0.70	0.53	40.7	39.1	35.2
Nov-09-1998	0.34	0.23	0.14	0.55	0.66	0.33	35.1	32.1	30.7
Feb-09-1999	0.20	0.13	0.51	0.28	0.21	0.85	33.5	30.7	34.2
Jun-18-1999	0.29	0.19	0.25	0.40	0.22	0.20	34.3	25.3	28.1
Sep-16-1999	0.27	0.32	0.25	0.60	0.67	0.54	36.9	35.5	36.8
Nov-17-1999	0.10	0.10	0.15	0.15	0.25	1.12	30.2	30.4	32.0
Mar-01-2000	3.9	<0.10	<0.10	2.08	0.37	0.45	28.4	34.8	31.6
Jun-07-2000	0.10	0.13	<0.10	0.23	0.37	0.14	26.2	21.5	20.3
Sep-27-2000	0.16	0.17	0.15	0.42	0.41	0.32	30.0	30.1	28.0
Station D									
Mar-12-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
Apr-03-1996	<0.10	0.1	<0.10	0.5	0.5	0.5	23.9	25.2	23.7
Jun-27-1996	0.4	0.4	0.2	0.26	0.35	0.19	32.9	26.2	28.5
Sep-04-1996	0.2	0.2	0.2	0.22	0.20	0.20	25.8	27.0	26.5
Nov-13-1996	0.14	0.25	0.17	0.14	0.12	0.12	•	•	•
Mar-12-1997	0.46	0.27	0.76	0.28	0.17	0.28	•	•	•
Jun-09-1997	0.12	<0.10	0.16	0.07	0.06	0.11	21.0	21.0	25.0
Sep-11-1997	0.53	0.29	0.33	0.24	0.22	0.16	27.7	28.5	22.6
Nov-17-1997	0.72	0.24	0.24	0.54	0.09	0.14	30.4	25.8	18.8
Mar-03-1998	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-03-1998	0.63	1.2	1.3	0.26	1.10	0.68	27.2	34.8	38.9
Sep-29-1998	0.64	0.47	0.50	0.29	0.27	0.21	34.6	27.7	26.5
Nov-10-1998	0.34	0.23	0.45	0.15	0.13	0.18	30.0	29.2	33.3
Feb-09-1999	0.29	0.40	0.38	0.18	0.27	0.51	26.6	28.0	32.6
Jun-18-1999	0.60	0.60	0.83	0.79	0.54	0.72	38.0	35.6	35.6
Sep-16-1999	0.68	0.53	0.81	0.44	0.51	0.85	36.7	35.0	39.8
Nov-17-1999	0.81	0.54	0.67	0.60	0.55	0.42	40.4	33.7	29.5
Mar-01-2000	0.71	0.83	0.34	0.41	1.10	0.19	33.6	31.2	19.8
Jun-07-2000	0.12	0.14	0.17	0.16	0.15	0.19	23.0	20.8	21.9
Sep-27-2000	0.39	0.22	0.35	0.18	0.13	0.22	37.0	25.8	23.5

Table 1 (continued). Summary of Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	µg/g, dry weight	µg/g, dry weight	µg/g, dry weight	%	%	%	%	%	%
Station E									
Mar-12-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
May-20-1996	0.1	0.1	0.1	0.7	1.0	0.7	41.1	35.8	34.5
Jun-27-1996	0.1	0.1	<0.1	1.08	0.45	0.40	37.9	32.7	30.9
Sep-04-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
Nov-13-1996	0.72	0.71	0.70	0.38	0.30	0.31	*	*	*
Mar-13-1997	0.82	1.0	1.0	0.12	0.16	0.06	*	*	*
Jun-09-1997	1.5	1.6	1.5	0.65	0.72	0.74	44.0	40.0	44.0
Sep-11-1997	1.6	1.3	1.9	0.69	0.52	0.78	42.0	34.2	45.8
Nov-17-1997	0.83	2.0	1.2	0.29	0.31	0.39	29.3	27.7	29.3
Mar-03-1998	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-03-1998	NT	NT	NT	NT	NT	NT	NT	NT	NT
Sep-29-1998	0.24	0.18	0.25	0.16	0.18	0.21	31.6	26.7	26.8
Nov-10-1998	0.25	0.18	0.30	0.13	0.15	0.39	31.8	25.6	32.5
Feb-10-1999	0.32	0.48	0.78	0.32	0.54	0.45	37.4	38.0	43.5
Jun-18-1999	0.48	0.30	0.47	0.24	0.16	0.32	33.1	27.4	49.7
Sep-17-1999	0.96	0.54	0.20	0.44	0.24	0.08	44.0	29.9	8.2
Nov-18-1999	0.38	0.17	0.39	0.17	0.13	0.26	28.0	28.4	30.7
Mar-02-2000	0.19	0.13	0.23	0.32	0.13	0.23	36.0	36.2	27.1
Jun-07-2000	0.29	0.26	0.78	0.19	0.19	0.30	26.6	19.1	30.4
Sep-27-2000	0.54	0.46	0.93	0.20	0.23	0.51	33.4	29.3	29.4
Station F									
Mar-12-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-27-1996	0.6	0.5	0.2	0.69	0.58	0.18	41.9	33.3	28.9
Sep-05-1996	0.4	0.8	0.4	0.44	0.75	0.25	38.7	40.6	29.7
Nov-13-1996	0.24	0.40	0.25	0.05	0.16	0.05	*	*	*
Mar-13-1997	0.94	0.36	0.57	0.56	0.36	0.32	*	*	*
Jun-09-1997	0.12	0.14	0.35	0.08	0.12	0.26	26.0	20.0	29.0
Sep-12-1997	0.59	0.73	0.74	0.23	0.22	0.23	28.0	26.9	23.8
Nov-18-1997	1.3	1.9	1.4	1.16	1.43	1.12	47.3	46.9	44.6
Mar-04-1998	2.1	1.8	1.6	2.32	1.97	2.11	42.0	70.0	42.2
Jun-04-1998	0.66	1.0	1.3	0.49	0.59	1.48	34.8	31.2	50.7
Sep-29-1998	0.33	0.48	0.59	0.26	0.31	0.23	26.8	26.1	29.2
Nov-10-1998	0.28	0.55	0.70	0.21	0.26	0.33	26.7	33.7	29.0
Feb-10-1999	0.59	0.56	0.93	0.40	0.32	0.19	33.1	30.5	31.6
Jun-18-1999	0.37	0.52	0.70	0.22	0.27	0.37	29.8	26.3	28.5
Sep-17-1999	0.53	0.65	0.62	0.49	0.53	0.22	35.5	36.8	28.6
Nov-18-1999	0.27	0.25	0.42	0.33	0.24	0.26	36.5	28.9	29.3
Mar-02-2000	0.35	0.45	0.59	0.29	0.26	0.32	23.8	23.3	21.2
Jun-07-2000	0.30	0.37	0.52	0.24	0.24	0.35	27.9	24.6	20.5
Sep-27-2000	0.43	0.68	0.53	0.34	0.24	0.34	36.8	37.1	33.8

Table 1 (continued). Summary of Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	µg/g, dry weight	µg/g, dry weight	µg/g, dry weight	%	%	%	%	%	%
Station I									
Jun-13-1996	0.4	0.4	0.3	1.6	1.3	1.2	7.8	17.2	24.9
Mar-13-1997	1.5	0.8	0.4	1.76	0.79	0.56			
Jun-03-1998	0.3	0.2	0.2	0.47	0.69	0.55	26.4	20.6	20.3
Jun-18-1999	4.8	4.5	4.4	1.90	1.89	1.96	16.1	25.1	25.9
Mar-01-2000	0.16	1.7	0.99	0.43	1.35	0.90	44.3	33.7	30.8
Jun-07-2000	4.4	2.2	1.7	1.92	1.55	1.39	4.6	20.9	20.1
San Luis Drain - Annual Survey									
30' South of Check 1 (1-2 C)									
Jun-10-1997	9.6	47	26	1.19	1.93	1.69	36.0	51.0	52.0
Jun-03-1998	22	9.7	29	1.49	1.49	1.55	49.7	44.8	44.9
Jun-16-1999	5.3	8.5	59	0.81	0.97	2.13	50.2	39.8	58.7
Jun-05-2000	14	15	15	1.33	1.55	1.11	54.0	53.6	40.1
Midpoint of Checks 1 & 2 (1-2 B)									
Jun-10-1997	39	96	51	2.11	2.25	1.56	56.0	53.0	47.0
Jun-03-1998	64	68	8.3	1.53	1.71	1.31	56.3	52.7	55.4
Jun-16-1999	8.8	11	14	1.30	1.45	1.53	62.9	57.6	55.8
Jun-05-2000	9.4	8.4	18	1.35	1.27	1.46	65.9	59.6	57.1
50' North of Check 2 (1-2 A)									
Jun-10-1997	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-03-1998	15	NT	21	0.65	NT	0.97	42.6	NT	38.2
Jun-16-1999	19	64	71	1.99	2.68	2.27	35.5	49.0	54.9
Jun-05-2000	14	29	67	0.85	1.12	1.66	25.0	32.2	44.1
50' South of Check 10 (10-11 C)									
Jun-10-1997	7.2	15	31	1.28	1.34	2.67	50.0	57.0	42.0
Jun-04-1998	21	39	17	0.72	1.66	1.43	44.0	62.6	56.4
Jun-16-1999	19	75	16	0.93	2.07	1.34	43.8	61.5	52.8
Jun-05-2000	47	84	41	1.23	1.65	1.85	49.6	57.1	60.9
Midpoint of Checks 10 & 11 (10-11 B)									
Jun-10-1997	11	12	NT	1.57	1.16	NT	59.0	48.0	NT
Jun-04-1998	7.5	8.7	17	0.91	0.93	1.43	54.0	45.1	72.6
Jun-16-1999	26	8.4	6	1.24	0.89	0.56	51.5	52.8	39.4
Jun-05-2000	7.5	22	5.8	1.28	0.99	0.93	61.4	52.8	53.2
50' North of Check 11 (10-11 A)									
Jun-10-1997	24	43	39	1.41	1.97	1.83	48.0	57.0	53.0
Jun-04-1998	18	55	50	1.14	2.57	1.68	47.2	61.2	53.5
Jun-16-1999	14	26	45	0.61	1.82	1.56	34.7	47.1	53.1
Jun-05-2000	12	58	51	0.66	2.55	1.69	32.1	64.4	54.1

Table 1 (continued). Summary of Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	µg/g, dry weight	µg/g, dry weight	µg/g, dry weight	%	%	%	%	%	%
50' South of Check 14 (14-15 C)									
Jun-11-1997	7.1	34	8.0	1.54	2.62	1.93	63.0	70.0	63.0
Jun-04-1998	31	11	42	0.85	1.96	1.11	45.2	67.4	42.3
Jun-16-1999	4.0	11	13	1.00	1.87	1.30	60.3	63.6	62.0
Jun-05-2000	5.3	4.8	45	1.34	1.36	2.41	60.6	41.0	63.1
Midpoint of Checks 14 & 15 (14-15 B)									
Jun-11-1997	2.9	22	10	0.38	1.11	1.91	29.0	49.0	56.0
Jun-04-1998	3.4	3.4	5.7	1.04	1.08	1.17	55.2	54.9	58.0
Jun-17-1999	3.0	3.1	3.0	0.95	0.96	0.94	58.0	56.0	52.6
Jun-06-2000	3.3	4.1	3.1	1.03	0.99	0.93	56.0	52.5	53.3
50' North of Check 15 (14-15 A)									
Jun-11-1997	40	48	3.8	2.37	2.83	0.59	63.0	67.0	63.0
Jun-04-1998	29	47	59	1.46	2.87	3.21	51.8	65.5	68.7
Jun-17-1999	43	76	76	3.64	3.23	2.84	61.9	65.2	63.5
Jun-06-2000	23	76	55	0.79	2.42	2.32	35.3	53.5	53.0
Midpoint of Checks 17 & 18 (17-18 B)									
Jun-10-1997	2.7	3.5	3.8	0.67	0.80	1.82	46.0	45.0	66.0
Jun-03-1998	2.0	2.8	2.7	0.57	0.83	0.90	24.8	34.1	44.9
Jun-17-1999	2.3	1.6	1.6	0.59	0.71	0.52	45.5	37.9	40.3
Jun-06-2000	2.2	2.0	1.9	0.76	0.66	0.59	36.3	38.9	38.9
50' North of Check 18 (17-18 A)									
Jun-10-1997	48	66	100	2.37	1.92	2.98	57.0	54.0	60.0
Jun-03-1998	35	65	75	1.25	2.39	2.33	38.0	53.8	57.4
Jun-17-1999	38	100	87	1.11	5.19	3.16	47.6	62.2	61.6
Jun-06-2000	26	49	43	0.81	1.84	1.54	35.6	47.9	45.7

NT = Not Tested
* = Lost Data
Laboratory: March 1996 to September 1996 USBR Laboratory / Sacramento
October 1996 to Present USGS Laboratory / Denver
Significant Digits: Selenium, 2 Organic Carbon, 2 or 3 Percent Moisture, 2 or 3
Reporting Limit: Selenium, 0.01 ug/g

Table 2. Sediment Monitoring to Measure Laboratory Precision (Duplicates)

Station	Sample Type	Sampling Date	Original ug/g	Re-sample ug/g	Quality Control Duplicate ug/g	Re-sample ug/g	RPD Per Cent
Water Year 1997							
B	3-8 cm	Nov-12-1996	41	43	26	28	44.8
E	3-8 cm	Mar-13-1997	1.0		0.96		4.1
B	whole	Mar-13-1997	42		41		2.4
C	3-8 cm	Jun-09-1997	0.20		0.20		0.0
B	3-8 cm	Jun-10-1997	27	31	18	19	40.0
A	3-8 cm	Jun-10-1997	4.2		4.3		2.4
1-2 B	whole	Jun-10-1997	51		54		5.7
10-11 C	0-3 cm	Jun-10-1997	7.2		7.2		0.0
14-15 B	3-8 cm	Jun-11-1997	22		21		4.7
17-18 A	whole	Jun-10-1997	100		86		15.1
B	whole	Sep-11-1997	48		43		11.0
A	whole	Sep-11-1997	50	48	21	23	81.7
Water Year 1998							
C	3-8 cm	Nov-17-1997	0.10		0.10		0.0
E	0-3 cm	Nov-17-1997	0.83		0.89		7.0
B	3-8 cm	Mar-03-1998	41		40		2.5
A	whole	Jun-04-1998	7.0		6.6		5.9
D	3-8 cm	Jun-03-1998	1.2		1.1		8.7
17-18 A	whole	Jun-04-1998	75		79		5.2
1-2 B	3-8 cm	Jun-03-1998	68		76		11.1
10-11 C	3-8 cm	Jun-04-1998	39		39		0.0
10-11 A	0-3 cm	Jun-04-1998	18		22		20.0
A	3-8 cm	Sep-28-1998	23		23		0.0
E	whole	Sep-29-1998	0.25		0.25		0.0
Water Year 1999							
B	0-3 cm	Nov-09-1998	17		17		0.0
A	whole	Nov-10-1998	31		30		3.3
B	3-8 cm	Feb-09-1999	31		30		3.3
E	whole	Feb-10-1999	0.78		0.86		9.8
A	whole	Feb-10-1999	11		11		0.0
A	whole	Jun-17-1999	23	21	14	13	48.6
I	3-8 cm	Jun-18-1999	4.5		4.4		2.2
B	3-8 cm	Jun-18-1999	27		28		3.6
1-2 B	3-8 cm	Jun-16-1999	11		11		0.0
10-11 C	whole	Jun-16-1999	16		18		11.8
14-15 B	3-8 cm	Jun-17-1999	3.1		4.2		30.1
B	3-8 cm	Sep-16-1999	29		30		3.4
A	whole	Sep-17-1999	30		29		3.4
Water Year 2000							
B	whole	Nov-17-1999	39	44	14	16	94.3
A	whole	Nov-18-1999	4.3		3.8		12.3
I	whole	Mar-01-2000	0.99		0.97		2.0
B	whole	Mar-01-2000	29		30		3.4
A	whole	Mar-02-2000	2.4		2.4		0.0
I	3-8 cm	Jun-07-2000	2.2		2.3		4.4
D	whole	Jun-07-2000	0.17		0.15		12.5
1-2 C	whole	Jun-05-2000	15		14		6.9
10-11 C	whole	Jun-05-2000	41		41		0.0
10-11 A	whole	Jun-05-2000	51		49		4.0
17-18 B	3-8 cm	Jun-06-2000	2.0		2.0		0.0
A	whole	Sep-27-2000	70	65	120	111	52.6
D	whole	Sep-27-2000	0.35		0.36		2.8

Table 3. Sediment Monitoring to Measure Repeatability (Replicates)

Station	Sample Type	Sampling Date	Original ug/g	Replicate ug/g	Absolute Difference ug/g	RPD Per Cent
Water Year 1997						
A	0-3 cm	Jun-10-1997	48	30	18	46.2
A	3-8 cm	Jun-10-1997	66	53	13	21.8
A	whole	Jun-10-1997	100	77	23	26.0
Water Year 1998						
14-15 C	0-3 cm	Jun-04-1998	31	14	17	75.6
14-15 C	3-8 cm	Jun-04-1998	11	19	8	53.3
14-15 C	whole	Jun-04-1998	42	24	18	54.5
Water Year 1999						
A	0-3 cm	Jun-17-1999	2.5	3.1	0.6	21.4
A	3-8 cm	Jun-17-1999	2.7	3.0	0.3	10.5
A	whole	Jun-17-1999	23	4.2	18.8	138.2
1-2 C	0-3 cm	Jun-16-1999	5.3	7.6	2.3	35.7
1-2 C	3-8 cm	Jun-16-1999	8.5	10	1.5	16.2
1-2 C	whole	Jun-16-1999	59	29	30	68.2
Water Year 2000						
A	0-3 cm	Jun-06-2000	2.6	2.5	0.1	3.9
A	3-8 cm	Jun-06-2000	2.8	3.1	0.3	10.2
A	whole	Jun-06-2000	3.0	4.2	1.2	33.3
14-15 C	0-3 cm	Jun-06-2000	5.3	4.0	1.3	28.0
14-15 C	3-8 cm	Jun-06-2000	4.8	5.3	0.5	9.9
14-15 C	whole	Jun-06-2000	4.5	7.8	3.3	53.7

Sediment Quantity in the San Luis Drain

Joseph C. McGahan,
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GRASSLAND BYPASS PROJECT

Introduction

The purpose of this aspect of the Grassland Bypass Monitoring Program (Monitoring Program) is to determine the changes in quantity and movement of sediment in the San Luis Drain (SLD). This is accomplished by actual measurement of the sediment and using total suspended solids measurements at the inlet and outlet of the SLD. An annual increase in sediment in the SLD is expected since the maximum water velocity in the SLD is maintained at or below one foot per second. This low velocity prevents sediment within the drain from being mobilized, and allows suspended solids in the drain water to settle out.

Sediment Quantity Monitoring Performed by the San Luis and Delta-Mendota Water Authority

Section 4.4.1 of the Compliance Monitoring Program (USBR et al., 1996) describes the procedure to measure the quantity of sediment in the SLD. The Monitoring Program calls for the measurement of sediment in four reaches of the SLD (Reaches 1, 10, 14, and 17). Measurements of sediment depths were to be made using the Monitoring Program protocol. The locations of the sediment measurement points duplicated those of the March 1987 survey performed by Summers Engineering. The Monitoring Program calls for measurements to be made once per year.

The sediment in the SLD was measured in reaches 1, 10, 14, and 17, as required by the Grassland Bypass Monitoring Program. Measurements were made in accordance with the Monitoring Program. The results are reported by reach in comparison to the 1987, 1997, 1998, and 1999 survey.

Table 1 summarizes the results. The results are also shown graphically in Figure 1. The results indicate an increase of sediment in reaches 1, 10, and 17 as compared to the 1999 survey. The sediment in reach 14 decreased by 564 cubic yards, or 5% from 1999. The overall net gain of sediment is expected as the flow velocities within the SLD are kept at or below one foot per second.

Total Suspended Solids Measurements

The Monitoring Program calls for total suspended solids (TSS) measurements as part of the water quality monitoring. These measurements were to be taken just downstream of the inlet to the SLD (Station A) and just upstream of the outlet (Station B). Measurements were taken on a weekly basis at these sites. The monthly average data are shown for WY's 1997, 1998, 1999, and 2000 in Table 2. Overall, the WY 2000 data show that TSS concentrations at Site A are higher than at Site B, by a factor of 1.95, averaged over the water year. One commitment of the GBP was to minimize flows so as to not cause sediment movement or suspension of sediments from the bottom of the SLD. The data suggest that the suspended sediments are settling in the SLD and that there is no net movement or suspension of sediments. This is consistent with the results of the sediment survey.

Survey Obstacles

In August 2000, the entire SLD was surveyed using the sediment survey method as prescribed by the Monitoring Program. The results of this survey yielded an increase of approximately 29% from 1999. Given the relatively calm nature of the water year (i.e., there were few significant and no extreme rainfall events, and reduced overall

**Table 1. 2000 San Luis Drain Sediment Survey
Survey Summary and Comparison**

Pool	Checks	Distance	March 1987**		June-Sept. 1997		July 1998		July 1999		August 2000	
		(miles)	Volume (cu yd)	Vol / mile (cu yd/mi)	Volume (cu yd)	Vol / mile (cu yd/mi)	Volume (cu yd)	Vol / mile (cu yd/mi)	Volume (cu yd)	Vol / mile (cu yd/mi)	Volume (cu yd)	Vol / mile (cu yd/mi)
1*	1 to 2	1 82	2,567	1,410	1,840	1,011	3,375	1,854	4,514	2,480	5,306	2,915
10*	10 to 11	1 46	2,647	1,813	2,708	1,855	2,781	1,905	3,101	2,124	3,669	2,513
14*	14 to 15	1 34	2,304	1,719	3,803	2,838	5,427	4,050	12,030	8,978	11,466	8,557
17*	17 to 18	0 68	1,885	2,772	3,006	4,420	2,435	3,581	3,205	4,713	3,477	5,113

* Required by Grassland Bypass Monitoring Program

discharges from the Grassland Drainage Area) this increase in sediment seems unreasonable.

In November 2000, another survey was performed in Reach 15, measuring sediment depth from a boat rather than from the bank. This survey measured approximately 15% less sediment than was measured with the Monitoring Program Method. Given the significant variance between the two methods, alternate procedures for sediment measurement are being considered for future surveys.

References

U.S. Bureau of Reclamation, et al. 1996. Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project, September 1996. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

Figure 1. San Luis Drain Sediment Survey Required Reaches

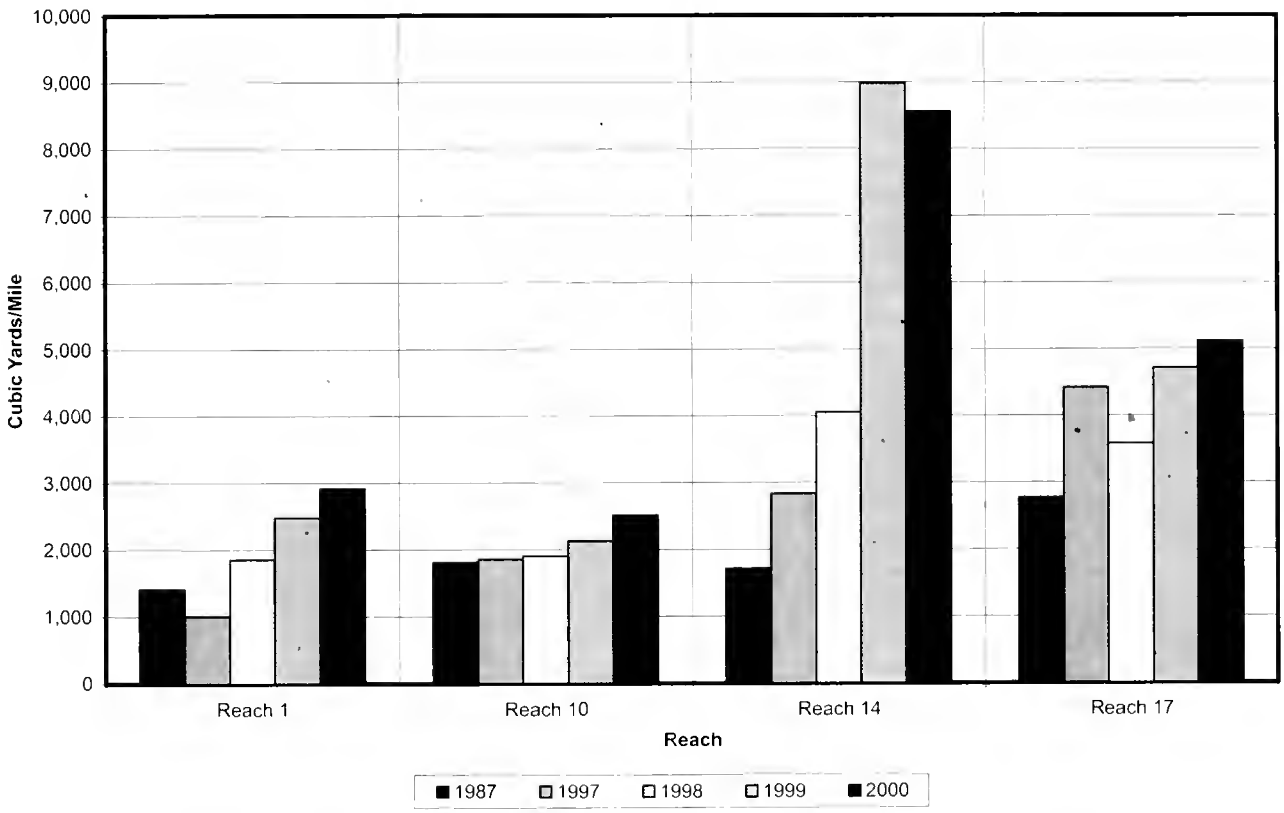

Table 2. Total Suspended Solids (Monthly Average)

Date	Station A TSS mg/L	Station B TSS mg/L
Oct. 1996	92	38
Nov. 1996	59	8
Dec. 1996	77	19
Jan. 1997	135	23
Feb. 1997	57	31
Mar. 1997	94	33
Apr. 1997	111	38
May 1997	101	56
Jun. 1997	107	27
Jul. 1997	136	21
Aug. 1997	140	22
Sep. 1997	111	22
WY 1997 Average	102	28
Oct. 1997	51	24
Nov. 1997	86	19
Dec. 1997	45	36
Jan. 1998	61	24
Feb. 1998	243	143
Mar. 1998	290	114
Apr. 1998	200	69
May 1998	270	86
Jun. 1998	123	42
Jul. 1998	171	49
Aug. 1998	94	44
Sep. 1998	37	33
WY 1998 Average	139	57
Oct. 1998	43	61
Nov. 1998	28	40
Dec. 1998	19	30
Jan. 1999	54	19
Feb. 1999	149	50
Mar. 1999	57	33
Apr. 1999	43	38
May 1999	97	60
Jun. 1999	160	68
Jul. 1999	145	65
Aug. 1999	166	61
Sep. 1999	69	71
WY 1999 Average	86	49
Oct. 1999	73	57
Nov. 1999	62	43
Dec. 1999	26	51
Jan. 1900	67	64
Feb. 1900	250	71
Mar. 2000	148	57
Apr. 2000	134	69
May 2000	165	45
Jun. 2000	136	63
Jul. 2000	99	53
Aug. 2000	120	58
Sep. 2000	59	57
WY 2000 Average	111	57

Victor Stokmanis,
U.S. Bureau of Reclamation

Data Quality Objectives

The Data Collection and Reporting Team (DCRT) uses the laboratory data from this project to support the determination of whether selenium (Se) levels in the Grassland Bypass exceed regulatory compliance levels. Because individuals use the data generated by this program for regulatory, compliance, and baseline monitoring purposes, the data must be of the highest degree of reliability. Sample collection from different environmental media and analytical methods performed by the laboratories must adhere to the guidelines established in the quality assurance project plan (QAPP).

Quality Assurance Project Plan

The QAPP defines the data quality objectives (DQOs) for the Monitoring Program, and each agency has established DQOs for their environmental measurements. The QAPP addresses both quantitative goals, including precision, accuracy, and completeness, and qualitative goals, including representativeness and comparability.

The QAPP includes all the requirements identified in the August 1994 Draft Interim Final, "U.S. EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations," EPA QA/R-5. It describes quality assurance/quality control (QA/QC) protocol associated with each agency's sample collection and laboratory activities; provides acceptance criteria for data validation procedures; and describes corrective actions to be taken when data fail to meet such criteria. The Data Collection and Reporting Team (DCRT) tailored the QAPP specifically to provide the necessary protocol for the documentation of QA/QC activities.

Quality Assurance Oversight

QA/QC oversight for the Monitoring Program is the responsibility of the U.S. Bureau of Reclamation (USBR). A QA/QC oversight manager (QAQCOM) serving in a cooperative capacity ensures the implementation of commitments, guidelines, practices, and protocols outlined in the QAPP in compliance with the goals and objectives of the project. The QA staff of the U.S. Bureau of Reclamation's Mid Pacific Region located in Sacramento, CA (Reclamation) carries out this oversight role. They use guidelines, protocols, and criteria established in the QAPP to monitor and validate data collected by Reclamation personnel and to assess the data collection and validation processes used by the other participating agencies. When Reclamation identifies a noncompliance QA issue, they notify the appropriate QA Officer, and the agency implements corrective actions to resolve the problem. Reclamation brings any unresolved issues between the QAQCOM and a participating agency's QA Officer to the attention of the Data Collection and Reporting Team (DCRT) for resolution.

As part of the QA oversight responsibility, Reclamation conducts audits of all participating environmental laboratories and reviews the data collection activities of the participating agencies for adherence to protocol.

Sampling groups participating in the Monitoring Program conduct system audits of one another's protocols by reviewing the sampling method in the field. For example, CDFG conducted a system audit of USFWS's sampling group and vice versa.

Quality Assurance Accomplishments

Laboratory Performance and System Audits

USBR's QA staff conducted performance and system audits of the following laboratories:

Laboratory / Location	Date(s)	Analysis Type
Trace Substance Laboratory in Rolla, Missouri	April 30 & May 1, 1996	Tissue Analysis
Severn Trent Services Laboratory in West Sacramento, California	October 10, 1996	Water Analysis
U.S. Geological Survey's Geological Division Laboratory in Denver, Colorado	December 2 & 3, 1998	Sediment Analysis
Twining Laboratory in Fresno, CA	June 22 & 23, 1999	Water Analysis
South Dakota State University Laboratory in Brookings, South Dakota	September 23, 1999	Water Analysis
Water Pollution Control Laboratory in Rancho Cordova, California	January 13 & 14, 2000	Tissue Analysis
Weck Laboratories in City of Industry, California	August 10 & 11, 2000	Water Analysis
BES Laboratory in Pleasant Hill, California	September 28, 2000	Toxicity Analysis

During 2000, the QA staff was able to audit the Water Pollution Control Laboratory, Weck Laboratories, and BES Laboratory. The audit process involves an initial demonstration of performance using external quality assurance samples followed by a review of the latest version of the laboratory's QA Manual, the laboratory's performance study results for the past three years, and the laboratory's most recent internal or

external audit report with corrective actions. Once the laboratory has demonstrated good performance and passed the initial document review process, the QA staff will conduct an on-site system audit. During the on-site system audit, the USBR QA staff reviews all of the detailed aspects of the quality system to ensure laboratory personnel understand and adhere to the protocols cited in the laboratory QA manual. The auditors then send an audit report which addresses all of the deficiencies identified during the system audit to the laboratory with a recommended time frame for the laboratory to respond, implement and document the corrective actions. The following tables are examples of how Reclamation summarized and documented performance sample results for the Water Pollution Control Laboratory and the Weck Laboratories (Tables 1 and 2).

Table 1. Water Pollution Control Laboratory, Rancho Cordova, CA Performance Sample Results for Selenium in Biological Tissue Date Completed: 10/05/99 Units = mg/kg

Sample ID	Result	True Value	% Recovery	Acceptance Limit
QA 396	5.05	5.63	90	80 - 120
QA 397	1.26	1.40	90	80 - 120
QA 398	3.36	3.52	95	80 - 120

Table 2. Weck Laboratories, City of Industry, CA Performance Sample Results for Selenium in Water Date Analyzed: 05/11/00 Units = µg/L

Sample ID	Result	True Value	% Recovery	Acceptance Limit
QA 435	68.3	58.1	118	80 - 120

The QA staff was unable to obtain a set of performance check samples for toxicity testing and as a result, Reclamation performed only a system audit on BES laboratory. BES laboratory has performed well on annual performance evaluation toxicity bioassays for the Discharge Monitoring Report (DMR) Program. The U.S. EPA established the DMR program to check the performance of laboratories which complete any part of the NPDES monitoring program established under the Clean Water Act. In addition, the State of California requires laboratories under the Environmental Laboratory Approval Program (ELAP) to participate in the DMR Program for all tests approved by the State. The U.S. EPA supplies toxicity performance standards only to those laboratories participating in the DMR Program.

The three laboratories audited by the USBR QA staff in 2000 performed well on the system audit. Where Reclamation observed deficiencies during the on-site system audit, the laboratories have incorporated our recommendations or are in the process of implementing them.

Sample Collection System Audits

Participating agencies performed sample collection system audits on each other during 1997, and 1998. Since the methodology did not change, no audits were conducted during 2000.

Data Validation Activities

The following routine data validation activities were performed to ensure data reliability as stated in the QAPP:

Type of data & field logbooks	Validation Group
Sediment data from USBR	USBR QA staff
Water data from CVRWQCB	USBR QA staff
Biota data from USFWS	USBR QA staff
Toxicity data from BES	USBR QA staff
Field logbooks from USBR's sampling group	USBR QA staff

Data Validation Methods

The QAQCOM is responsible for ensuring the participating agencies properly validate their analytical results, identify problems with their analytical data, and contact their respective laboratories to initiate corrective actions. To accomplish these tasks, USBR QA staff routinely reviews and validates the data produced by the participating agencies.

USBR QA staff assesses the validity of the analytical results by comparing QC results to acceptance criteria identified in Table 9 of the QAPP. The guidelines address both internal and external QC sample results. The QAPP defines internal QC samples as those check samples incorporated by the laboratories performing the work and defines external QC samples as those check samples submitted to the laboratories by the contracting agency. USBR QA staff ensures agencies are incorporating correct numbers and types of external QC samples into each batch of field samples during the data validation process and addresses any nonconformance issues with the agencies directly. Another assessment activity performed by the QA staff is to make sure participating

agencies spike their external QC check samples at concentrations near historical levels as a means of ensuring better sample accuracy.

As part of this data validation process, Reclamation brings laboratory QC summary report problems to the attention of the each agency's QA officer. The QA Officers then address these problems with the laboratories. For example, QA Officers may request laboratories take proper corrective actions on internal QC check sample results outside of established control limits. Reclamation also checks data packages to ensure laboratories document details of their corrective actions in the case narrative section or as footnotes in the QC summary section.

Reviewing data packages to identify possible outliers is another part of the validation process. Once USBR QA staff identifies a data point as a possible outlier, they promptly request the laboratory re-analyze the sample. For example, USBR QA staff identified the sediment sample selenium result of 3.9 µg/g for monitoring Site C collected on March 1, 2000 as a potential outlier. Project field personnel sampled this site fifteen times from November 1996 through September 2000 with the following selenium results: 0.2, 0.2, 0.1, 0.2, 0.1, 0.3, 0.4, 0.3, 0.2, 0.3, 0.3, 0.1, 3.9, 0.1, 0.2 µg/g respectively for the 0-3 cm depth as shown in Table 3. Upon re-analyzing the sample demonstrating the 3.9 µg/g selenium result, the laboratory confirmed the original result (Table 3). Although confirmed potential outlier measurements will remain in the database, periodically USBR QA staff reassesses them as the laboratory generates additional data points for the site by conducting a statistical trend analyses study. Once a data point is statistically proven to be an outlier, USBR QA staff will either flag the data point as a questionable measurement or they will remove the data point from the database entirely.

Table 3. Grassland Bypass Program San Luis Drain Sediment Monitoring Selenium Levels (µg/g, dry weight)

Site C	0-3 cm	Re-analyzed Result	Relative % Difference	Confirmation Acceptance Level
November 12, 1996	0.2	—	—	—
March 12, 1997	0.2	—	—	—
June 09, 1997	0.1	—	—	—
September 11, 1997	0.2	—	—	—
November 17, 1997	0.1	—	—	—
June 04, 1998	0.3	—	—	—
September 28, 1998	0.4	—	—	—
November 09, 1998	0.3	—	—	—
February 09, 1999	0.2	—	—	—
June 18, 1999	0.3	—	—	—
September 16, 1999	0.3	—	—	—
November 17, 1999	0.1	—	—	—
March 01, 2000	3.9	4.3	9.8	≤ 35%
June 07, 2000	0.1	—	—	—
September 27, 2000	0.2	—	—	—

As a means of assessing both laboratory performance and field sampling homogenization techniques, Reclamation collected four duplicate sediment samples from the San Luis Drain and two duplicate sediment samples from Mud Slough and submitted them to the U.S. Geological Survey, Denver Laboratory for selenium analyses. These duplicate sample results (Table 4) provided information on both laboratory performance (precision) and ability of field personnel to properly homogenize samples. USBR QA staff determined which results met their established acceptance level. The USBR QA team concluded the values in Table 4 demonstrated acceptable analytical precision by the laboratory and sample homogenization techniques by USBR's field sampling team.

Table 4. Quality Assurance Results
GBP Sediment Monitoring Program
Conducted June 05-07, 2000
Duplicates to Measure Laboratory Precision

Site Location	Selenium Levels	Relative Percent Difference (RPD)	Duplicate Acceptance Criteria
SLD 1/2C (whole)	15/14 μg/g	6.9%	≤ 35%
SLD 10/11C (whole)	41/41 μg/g	0.0%	≤ 35%
SLD 10/11A (whole)	51/49 μg/g	4.0%	≤ 35%
SLD 17/18B (3-8)	2.0/2.0 μg/g	0.0%	≤ 35%
Site I (3-8)	2.2/2.3 μg/g	4.4%	≤ 35%
Site D (whole)	0.17/0.15 μg/g	0.02	± RL

USBR QA staff reviews all field calibration sheets obtained from each agency performing field sampling for documentation of routine instrument calibrations to ensure reliable field measurements for this project.

QA Issues of Concern

USBR QA staff found all the agencies adhered to the protocols outlined in the QAPP. One concern involves some of the agency's reluctance to supply laboratory data to Reclamation. Specifically, on numerous occasions upon requesting data from the USFWS for a specific sampling period, the USFWS failed to respond to Reclamation's request. The CVRWQCB provided copies of data summary sheets but denied Reclamation's request to copy field sheets due to proprietary information on these sheets. In recent meetings, these issues with the USFWS and the CVRWQCB have been resolved. Reclamation requires copies of the laboratory reports and field sheets from the participating agencies in order to perform its reviews adequately.

Uncertainty Associated with Environmental Measurements

As with all quantitative measurements, there is a degree of uncertainty associated with the values provided. This is especially true for environmental data where measurement error may be introduced in the sample collection phase as well as in the laboratory service phase. Program participants and the public need to understand that values presented in laboratory reports are not absolute, but rather represent values with associated precision and accuracy uncertainties as defined in Table 9 of the QAPP. In addition, as the concentration of the parameter approaches the limit of detection for the particular analytical method, the level of uncertainty of the result increases significantly as shown in Figure 4 of the QAPP. The data user needs to understand the degree of uncertainty or the confidence limits associated with the data.

Summary

With few exceptions, the participating agencies in the Monitoring Program complied with the protocols outlined in the QAPP. Adherence to the QAPP ensured the reliability of the data collected and provided the necessary documentation to support the validity of the measurements. Where exceptions did occur, USBR's QA staff was able to quickly identify and address the issues, thereby ensuring the data quality objectives of the program.

During 2000, the USBR QA staff conducted thorough audits of three program laboratories, and continually performed routine data review and validation of the data collected throughout the year. In order to perform QA oversight duties, Reclamation requires full cooperation from the participating agencies. In performing QA oversight, Reclamation serves to remind agencies of the need to adhere to protocols established in the QAPP.